THE JOHNS HOPKINS UNIVERSITY

SCHOOL OF MEDICINE

UNPUBLISHED PRELIMINARY DATA

STATUS REPORT

BIOLOGICAL EXPERIMENT IN SPACE

PSYCHOCARDIOVASCULAR REACTIONS DURING CONDITIONS OF WEIGHTLESSNESS IN AN ORBITING SATELLITE

From 1 October, 1963 to 30 September, 1964

Baltimore, Maryland 21205

N O T E

This is a status report concerning work done under NASA Grant NsG-520 from October, 1963 to October, 1964. The scientific information released in this document was obtained under policies and standards of The Johns Hopkins University School of Medicine. This is not a classified document.

Jorge Perez-Cruet

Jorge Perez-Cruet, M.D.
Director and Responsible
Investigator of the Grant

STATUS REPORT

BIOLOGICAL EXPERIMENTS IN SPACE

PSYCHOCARDIOVASCULAR REACTIONS DURING CONDITIONS OF WEIGHTLESSNESS IN AN ORBITING SATELLITE

From 1 October, 1963 to
30 September, 1964

Jorge Perez-Cruet, Responsible Investigator
The Pavlovian Laboratory, The Johns Hopkins
University School of Medicine

Contract Number NsG-520

Supported By:

National Aeronautics and Space Administration
Ames Research Center
Moffett Field, California

I N D E X

A B S T R A C T

AD NO.____________________ ACCESSION NO.____________________

1. Preparing Institutions: The Pavlovian Laboratory
   The Johns Hopkins University
   School of Medicine
   Department of Psychiatry

2. Title of Report: Psychocardiovascular Reactions During Conditions of Weightlessness in an Orbiting Satellite

3. Responsible Investigator: Jorge Perez-Cruet, M. D.

4. Pages: 92

5. Contract Number: NsG-520

6. Supported by: National Aeronautics and Space Administration
   Ames Research Center
   Moffett Field, California

Working Hypotheses:

The main purpose of our experiments is to determine various psychocardiovascular reactions during 7 to 14 days of weightlessness in an orbiting satellite. It is expected that such prolonged periods of weightlessness can produce significant changes in the distribution of blood to vital organs (brain, kidneys and skin). These cardiovascular changes can be associated with marked changes in heart rate, blood pressure (systolic and diastolic) and various cardiac arrhythmias (ECG). It is also anticipated that under weightless conditions exceeding 7 days the homeostatic mechanism sustaining terrestrial psychocardiovascular reactions can be disrupted causing serious changes in the performance of the organism.

Experimental Design (Include Ground Based and/or Flight Controls):

The subjects will be rhesus monkeys. Two indwelling Statham micro-transducers will be implanted intra-arterially in the carotid and hypogastric arteries. One blood pressure transducer will measure blood pressure above the heart level, the other below the kidney level. Three electromagnetic flow meters will be attached to three vital areas: (1) the carotid artery supplying the brain; (2) the renal artery supplying one kidney; and (3) the iliac artery supplying one extremity. The electrocardiogram will be monitored using implanted electrodes to determine heart rate changes, as well as cardiac arrhythmias.

If all cardiovascular reactions are monitored perfectly during the first half of the experiment (that is, 7 days in a 14-day weightless period), reactivity of the cardiovascular parameters will be tested by presenting signals to the animals (loud noise, lights) as well as during feeding periods. This will be of importance in determining whether the weightless conditions have altered the terrestrial reactivity to these stimuli. The same procedure will be repeated prior to the re-entry period and sometime after the recovery period to check for possible sequelae of the prolonged weightless period.

In the event any detrimental effects of prolonged weightlessness should appear after the first 7 days of extraterrestrial flight conditions, then provisions should be available to try the intra-arterial injections of drugs which may improve the cardiovascular disorders and restore it to a normal level.

The experiment is to be coordinated with neurophysiological (EEG, EMG, postural reflexes) and behavorial profiles on the basis of proposals submitted by other experimenters.

GENERAL EXPERIMENTAL REQUIREMENTS

Investigator: Jorge Perez-Cruet, M. D. Date: 4/1/64 to 9/30/64

Project Title: Psychocardiovascular reactions during conditions of weightlessness in an orbiting satellite.

1. Lead Time (Including feasability, ground experiments, engineering, etc.):

   Approximately 2 months

2. Time

   a. Pre-launch hold time -
      Optimum: Approximately 2 hours

      Maximum: Approximately 5 hours

   b. Orbit time (time at zero gravity) -
      3 day: Desired

      14 day:

      Other:

   c. Maximum Post-flight time (from touchdown to experimenter):

      Approximately 24 hours

3. Radiation exposure (desired and/or tolerated) -

   Minimum: 0 rads

   Maximum: 200 rads

   Optimum: not over 100 rads

4. Environmental conditions required (tolerable range)

   a. Temperature -

      Prelaunch: 35 - 80° F

      Flight: same

      Recovery: 35 - 100° F

   b. Atmospheric -

      Composition: Same as ground

Pressure: ½ - 2 atm.

c. Other (light, humidity, etc.):

Humidity in the comfortable range of 50 - 60%.
Normal cabin light (if accomodated).

5. Operational constraints imposed by experiment -

a. Maximum permissable acceleration: Approximately 10 g.

b. Maximum permissable spin at launch and re-entry: Does not matter.

c. Does slow rotation or tumbling affect experiment? It may or may not. This would be determined after the experiment.

d. Other?

6. Weight Estimates of Flight Package -

a. Biological material: Approximately 2 - 5 kilograms.

b. Total: About 4 - 7 kilograms.

7. Volume estimate of flight package (Dimensions) -

a. Biological Material: Approximately 40 x 20 x 10 cm.

b. Total: Same.

8. Sensors and Telemetry -

a. Number of fulltime channels: 3. EKG, Pulmon. Vol. Flow, t^o (body)

b. Number of commutated channels: 4. Every 3 min., except continuous at launch and re-entry.

c. Maximum and minimum frequency response required: Between D.C. and 100 cps.

d. On board recordings: None.

e. Motion pictures? None.

f. Television? None.

9. Capsule power required (excluding capsule environmental)

   a. Power required: For radio transmission.

   b. Voltage and current other then 28 V.D.C.

      Instrumentation run on 12 V.D.C.

10. Funding

   a. Experimenter's funds:

   b. NASA help needed: Yes.

Progress in Instrumentation

A. Physiological:

A considerable number of instruments have been purchased to measure several physiological variables such as: blood flow, blood pressure, intra-arterial temperatures, pulse propagation time (pulse velocities) and plethysmography. Electrocardiograms and respirattion have been recorded with an Offner polygraph.

a. We have measured simultaneously four blood flows (carotid, aortic, femoral and renal) with Medicon series K-2000 flowmeters in acute experiments (See figure 1). We have also measured, under these conditions, arterial and venous blood pressures.

Tests have also been performed in chronic experiments involving dogs and primates. Dogs were used in order to avoid the excessive cost involved in the use of monkeys. Several monkeys were implanted successfully for periods ranging from 2 to 4 weeks. Figures 2, 3 and 4 illustrate several tracings of blood flows in primates. These implantations were working for periods longer than 2 weeks. Monkeys with transducer implantations which lasted less than 2 weeks were eliminated from our studies.

Figures 5, 6 and 7 show tracings of renal, aortic, two renals and carotid blood flows for more than one month in chronic studies involving dogs.

Techniques of implantation of the transducers used for measuring electromagnetic blood flow have been improved. Several difficulties were encountered initially in the implantation of these transducers in primates due to the fact, that in general, the size of their arteries was smaller than those of the dog. Also primates proved to be far more susceptible to infection than dogs.

Figure 8 illustrates the technique for implanting these flow-probes around the arteries. Photograph 1 illustrates the actual size of one of the transducers used in our primate studies.

b. Techniques for measuring blood pressure have been perfected and modified for the biosatellite preparation. Recordings of both central (ascending aorta or innominate trunk) and peripheral (lower third of the aorta below the renals) have been done in primates for periods of one or two months. Figures 9 and 10 illustrate central and peripheral blood pressure recordings in primates.

Figures 11 and 12 show chronic experiments in which blood pressures were monitored for several weeks in primates. Figure 13 shows blood pressure determinations in a primate that had been restrained completely in a simulated flight suit for a period of 19 days.

Techniques used in these experiments are described in detail in Section IV of this report - Blood Pressure Techniques, Part C.

These studies on blood pressure will be followed by a series of new experiments using implantable transducers for measuring blood pressure.

c. Techniques and electrodes for recording artifact free electrocardiograms (ECGs) have been developed. We have used teflon coated stainless-steel electrodes which have been implanted subcutaneously. Electrocardiograms have been taken in several monkeys using these techniques. Figure 14 shows an electrocardiogram taken from a monkey restrained in a chair. Figure 15 illustrates some effects of electric shock through the skin in the same primate.

d. Studies are now in progress to measure intra-arterial temperatures, plethysmography and pulse propagation time.

B. Control Systems and Recording Equipment:

Sound-attenuated booths and programming equipment has been purchased to study psychocardiovascular reactions which can be standardized for future space flights.

Photographs 2 and 3 show some of the control and recording equipment used in the initial phases of this project. Figure 16 illustrates the plans of the present complex-organization, still in progress, of sound-attenuated booths where primates will be programed in "simulated" space flight conditions, without handling, for several weeks.

The programming equipment has been tested in two primates in experiments involving psychocardiovascular reactions to sounds (orienting reflex to sound) and in classical conditioning experiments using a tone as a conditional stimulus and orange juice as an unconditional stimulus. This experiment will be explained in detail in Section V of this report - Experiments and Publications, Part A.

Figure 17 illustrates the logic and circuit diagram of transistorized equipment used for control and study of psychocardiovascular reactions. Figures 17 and 18 show the electronic circuits of two of the basic units. These units can be purchased already assembled in individual printed circuit cards. The assembly of several units and design of the logic is done by us.

Transistorized equipment was used because the electronic package will be compatible with the voltage supply and requirements used in space flights.

Programs for feeding schedules, collection of urine and feces, and monitoring of psychocardiovascular reactions are being designed.

A technician has been trained in computer techniques. Data has been transfered to punch card machines and analyzed in an IBM 1401 computer here at The Johns Hopkins University School of Medicine Computing Center. At present, programs for histogram, standard deviations, correlations and statistical analysis have been used in data collected in several experiments.

Progress in Techniques

A. Blood Flow Techniques:

Techniques for measuring blood flow were evaluated using Medicon flowmeters. In this technique we employed the electromagnetic flow meter principle.

Measurements of blood flow are extremely important in our studies because they will reveal accurately changes in blood distribution to organs.

At present there are several methods for measuring blood velocities and volume flow of blood. The electromagnetic technique, in our opinion, is presently one of the most useful techniques. Other good techniques now available are: sonar flow measuring systems and dilution dye techniques.

In our experience there are numerous problems on implantation of pick-up systems, no matter which techniques are used. The body has a natural way of reacting to any kind of implanted foreign material and unless proper surgical techniques are employed severe infections will ensue and damage the preparations.

Chronic implantations are extremely difficult to maintain depending on the training and experience of the investigator and technicians. Acute implantations hardly present any problem. In our hands, chronic implantations to measure blood flow have been kept in good condition for varying periods of time.

Implantations in large arteries (caliber greater 2.5mm) have a better chance to work for longer periods of time than implantations in small arteries. The most common offender is kinking of the arteries, but other causes of failure include infection and occlusion due to narrowing of the small lumen.

Problems of power supply pose another challenge. Most of the instruments which are available work on regular 120 AC volts power supply. Transistorized equipment is still under development.

At present we are planning to develop flow measurements which will be operated by 6 or 12 volts DC power supply using a different principle than the electromagnetic, but using the electromagnetic flowmeters as a calibration and refererence point for the new technique. This technique, if successful, will be more useful in the biosatellite studies.

Photographs 1 and 4 illustrate a 1 mm. in diameter blood flow-probe (Photo 1) and a 10 mm. in diameter flow-probe (Photo 4). The first is used in small arteries such as the renal artery and second is used in ascending aorta or other portions of the aorta in primates. Blood flow velocities are more accurate with the larger flow-probe (Photo 4).

Photograph 5 illustrates the assembly of three K-2000 flowmeters for measuring simultaneous blood flows in several arteries in our experiments.

B. Techniques for Implanted Electrocardiographic Leads:

After numerous trials in several years, I have found that the most suitable way of obtaining electrocardiograms in primates is by implanting them subcutaneously and passing them under the skin to suitable connectors in the skull or in the abdominal wall above the umbilicus.

Originally a stainless steel pedestal attached to the skull with screws and cranioplastic cement proved to be very stable and successful for several months. More recently, due to the fact that other experimenters will be using the skull for intracraneal electrode placements, we have developed techniques in which the electrodes are attached to a proper receptacle in the abdominal area which allows a free field in the cranium.

Two of the greatest problems in subcutaneous implantations of electrocardiographic leads are fastening the electrodes to the ribs and using electrode material with a good metal fatigue coefficient. Constant movements back and forth at certain places of the electrode leads usually dislodge them from the body or weakens the wires to a point where they are torn apart. Part of these problems has been solved by using teflon coated stainless-steel wires which had been used in the past for pacemaker implantation in humans. Sample #1 illustrates a small example of this wire.

The techniques for recording good electrocardiograms have been perfected to a point where we have almost perfect confidence that the recordings will work for months.

C. Blood Pressure Techniques:

Techniques have been developed to measure blood pressure in primates chronically. We have developed direct techniques for the recording of blood pressure using indwelling catheters in arteries. This technique has been tried successfully in several primates as shown previously in figures 11, 12 and 13. The technique consists of placing a blood pressure catheter in the femoral artery or in the iliac artery through the hypogastric artery and/or in the ascending aorta through the common carotid. This technique allows us to measure central (ascending aorta) and peripheral (femoral) blood pressures simultaneously. At present we have found that these catheters can be left without flushing for periods ranging up to a month. Developments are being made to determine if it is possible to prevent damping of the blood pressure after such prolonged periods without flushing. A very important aspect of this technique is that accurate direct blood pressure determinations are available at anytime. One of the main obstacles of the technique was the possibility of internal bleeding, but this problem has also been solved by using a ring suture around the artery and also around rings which are attached to the catheter. This ring suture prevents partial leaking points in the wall of the arteries. Monkeys and dogs have pulled out some of these catheters without causing fatal arterial bleeding.

Figure 19 illustrates the techniques for preparing the arterial catheters used in direct arterial implantations.

A big advantage that this technique offers is that Statham strain gauges of the type shown in photograph 6 can be employed. These blood pressure transducers can be activated by 6 volts DC and output signals could be amplified to telemetry systems.

Other techniques for measuring blood pressures have been explored. We have measured blood pressures with strain gauges in the form of cuffs which surround the arteries.

These extra-arterial techniques have a great advantage in that arteries are not punctured and thus arterial bleeding is minimized. Photograph 7 illustrates one of the extra-arterial blood pressure cuffs. Theoretically this principle is good but practically there are numerous disadvantages. Many problems were encountered, among them: (a) the calibration of blood pressure was difficult, and (b) relative blood pressure changes were obtained. In spite of some original failures, we will still attempt to explore the potentialities of this technique further.

A third blood pressure technique is that of implantable blood pressure transducers. These transducers offer the advantage that no flushing is required and that the strain-gauge pick-up is inside the arterial system. Furthermore, the voltage supplies are the same as that used in Statham gauges. Due to the fact that these intra-arterial catheters are more expensive, their use has been restricted until we have monkeys which are trained and suitable for space studies. Photograph 8 illustrates one of the intra-arterial transducers which was manufactured by Micro-Systems.

D. Techniques for Fixation of Physiological Transducers Outlets:

One of the greatest problems in chronic implantations has been the attachment of multiple wires and catheters coming from the animal to proper receptacles in a way that the animal can not destroy them. Invariably most monkeys have a tendency to pull anything which is attached to their bodies.

The most successful technique for avoiding pulling of wires is to fix them to a pedestal in the skull or to special attachments in the abdomen. In abdominal preparations casting with light plaster proved to be the most durable, but the technique needs more development. With the light cast we can measure electrocardiograms, blood pressure and blood flow. One of the problems with the cast is that at pressure points such as the shoulder joint a condition similar to "frozen shoulder" usually develops. Re-design of this technique is planned to avoid this condition. Another technique which we have explored is that of partial dressing with "aluminum" cloth and waterproof military adhesive. This technique has been more successful in avoiding infection because air circulates through the cloth. One of the major obstacles has been that the primates constantly pull the cloth, which eventually weakens until it is torn.

Stockinettes have been substituted for the aluminum cloth and they have been as good as the aluminum cloth. They offer an advantage in that the stockinette can be removed very easily every 3 to 4 weeks to determine if there are infections underneath the clothing. Sample #2 illustrates pieces of the aluminum cloth, stockinette and waterproof military tape used for wrapping and protecting the physiological preparation.

In future preparations we are trying to develop a combination of these techniques in such a way that the primates will be able to move the extremities, move around if desired and do planned behavorial tasks under weightlessness conditions.

Experiments and Publications

A. A total of 12 monkeys have been used in our experiments. In some of these animals techniques were tested and evaluated in terms of the Biosatellite requirements.

Methods and techniques have been modified so that the physiological parameters can be measured in the partially unrestrained animal under conditions to be encountered in prolonged weightlessness.

We have studied central and peripheral blood pressures in two monkeys which had been restrained in monkey chairs. We have found that fluctuations in central and peripheral blood pressures follow each other, that is, the blood pressure responses to stimuli were in the same direction. In general, the peripheral blood pressure is higher than the central blood pressure (see figures 11 and 12). In some monkeys, after implantation of the intra-arterial catheters, the blood pressure remained elevated for a week; thereafter, the level was lower and stable. Other monkeys were not affected by the procedure and they showed stable patterns in blood pressure.

Central blood pressures usually fluctuated between 175 to 150 mm Hg systolic and 110 to 70 mm Hg diastolic. Peripheral blood pressures usually fluctuated between 210 to 150 mm Hg systolic and 110 to 75 mm Hg diastolic. Blood pressures in monkeys which are completely undisturbed can be as low as 90/60 mm Hg.

One monkey was restrained completely for a period of two weeks. Under these extreme conditions blood pressure fluctuated between 180/110 to 160/75 mm Hg for the entire period (see figure 13). The monkey developed "frozen shoulder" and muscular atrophy of the extremities during this period of restraint. In spite of this complete restraint, the monkey was very aggressive and responded to usual stresses.

The effects of auditory signals of different frequencies (tones 256 cps and 512 cps) on blood pressure were tested in two monkeys. One monkey showed very little response to either auditory signal. Another animal showed a slight increase in blood pressure during auditory signals (10 mm Hg above prestimulus level). The same monkeys were trained using classical conditioning with food. Orange juice was given as an unconditional stimulus. The presentation and drinking of orange juice produced changes in the blood pressure in the two monkeys. In some experiments presentation of orange juice increased the blood pressure 30 mm Hg above pre-stimulus level. In the conditioning procedure two tones of different frequencies were used. The tones were presented for 6 seconds every two minutes. A tone (tone 256 cps) was always paired with orange juice. Another tone at a higher frequency (T512) was never paired with the presentation of orange juice. One tone was excitatory (tone 256) and it produced excitement in the animal. The other tone was inhibitory (tone 512) and produced no change. Experiments showing psychocardiovascular changes in blood pressure to the conditional stimuli during controls, conditioning and extinction are illustrated in figures 20 to 25.

In summary, we found that blood pressure conditioning can occur to an auditory conditional stimulus which is paired with food and that the monkeys can differentiate rapidly by not showing a blood pressure response to another auditory signal which is never paired with food.

B. In a series of monkeys we have studied the stability of blood flow measurements for prolonged periods of time. Blood flow-probes have been implanted in several arteries of the body including the carotid, femoral, renal and ascending aorta. The best results were obtained in monkeys with implantations in the carotid and ascending aorta. Implantations in the renal and femoral arteries were more difficult to maintain.

During the early phases of these studies we determined the variability in the size of different arteries in the body of primates. It was found that the diameter of the common carotid in monkeys weighing from 8 to 12 pounds varied between 1.5 to 3 mm. in diameter. The diameter of the ascending aorta for the same size of monkeys varied between 9 to 11 mm.; of the renal arteries at the origin of the aorta varied between 1.5 to 2.5 mm.; and of the femoral arteries varied between 1.5 to 2.5 mm. These measurements were necessary in order to obtain the correct size of flow-probes which are available commercially.

C. Some experiments have been performed in dogs to standardize some of the procedures and techniques which were employed in primate work. A total of 32 dogs have been employed in these studies. Twelve dogs were employed in acute experiments involving cardiac arrest and other procedures in order to determine the reliability of the instrumentation which had been used in the primate experiments.

D. Techniques have been developed in dogs for chronic collection of urine. These techniques will be used in primate preparations after further evaluation. Dogs have been kept for periods ranging from one week to three months. This technique will solve the problem of urine collection in space flights.

E. Publications:

1. Systolic Blood Pressure Changes During Two Beat Sinus Arrhythmia.

2. The Effect of Cardiac Arrest With Closed Chest Massage on Classical Conditional Reflexes.

(See abstracts 1 and 2).

Abstract 1

Systolic Blood Pressure Changes During Two Beat Sinus Arrhythmia. J. Perez-Cruet*, J.E.O. Newton and W.H. Gantt.
Pavlovian Lab., The Johns Hopkins University School of Medicine, Baltimore, Md.

Two beat sinus arrhythmia is a special type of arrhythmia in which, after a long pause, the sinoauricular node initiates two successive beats, followed by another long pause. This type of arrhythmia resembles cases of premature contractions (coupling). We have observed this type of arrhythmia in about 80% of our dogs. It usually occurs sporadically and in many instances is associated with a fast respiratory rate. In seven unanesthetized dogs, direct systolic blood pressures were measured during two beat sinus arrhythmia. During the second beat the systolic pressure was increased 4 to 10 mm Hg from the pressure level of the first beat except in one dog in which the systolic pressure always decreased during the second beat. The incidence of systolic blood pressure increase on the second beat is greater in central pressures (90 to 100% occurrences) than in peripheral pressures (43 to 80%). Three mechanisms are responsible for the increase in blood pressure during the second beat: 1) changes in cardiac output, 2) peripheral resistance, and 3) cardiac rate. Respiratory rate is not necessarily responsible for these changes (Perez-Cruet, et. al., Fed. Proc. 20, 1961 p.89). During the second beat the stroke volume is usually decreased as well as the amplitude of peripheral optical plethysmography. The mechanism for the consistent decrease in systolic pressure in the second beat during two beat sinus arrhythmia in one dog is not known and is under investigation. In summary, the study showed that usually in two beat sinus arrhythmia the systolic blood pressure increases slightly during the second beat.
(Supported by NHI grant HE-06945-03 and NASA grant NsG 520)
Reprinted from THE PHYSIOLOGIST, Vol. 7, No. 3 - August 1964
Printed in the U. S. A.

Abstract 2

The Effect Of Cardiac Arrest With Closed Chest Massage On Classical Conditional Reflexes.

Patrick E. Brookhouser*, Jorge Perez-Cruet and James R. Jude*, Pavlovian Lab. and Dept. of Surgery, The Johns Hopkins University School of Medicine, Baltimore, Md.

This study was designed to determine the effect of prolonged cardiac arrest with closed chest massage on the retention of Pavlovian motor and cardiac conditional reflexes (CRs). Pavlovian conditioning was established in unanesthetized dogs for several weeks using a sound proof room. Cardiac arrest and resuscitation were performed in an operating room under anesthesia. Five dogs with well established motor and cardiac CRs were used. Only three dogs survived ten minute periods of cardiac arrest with massage. Massage rate was about 100 chest compressions per minute. Blood pressure during massage varied between 60/15 to 140/80 mm Hg with a 35% reduction in carotid flow. Two dogs showed some impairment of motor and cardiac CRs 24 to 48 hours after cardiac arrest with massage. The CRs were fully restored after three days of constant reinforced trials or rest. In one dog, the effects of anesthesia, electric shock through the heart, and surgical procedures were controlled as the main cause of this temporary loss. The temporary impairment of CRs indicates that learned reactions were affected due to some organic cortical damage produced probably by a reduced blood supply to the brain.

(Supported by NHI grant HE-06945-03 and NASA grant NsG 520)
Reprinted from CLINICAL RESEARCH, Vol. XII, No. 4, p.440 - December, 1964.

Status and Summary

For the past twelve months, techniques and methods have been developed for a biological experiment in space under conditions of weightlessness which will last 2 to 3 weeks. Several technical problems have been solved which will allow us to measure several psychocardiovascular reactions in space. In a few months, we plan to have a fully instrumented biological preparation which will meet the requirements for space flight.

In summary, several instrument limitations and problems have been encountered and mentioned in this report. New techniques have been developed for recording blood pressure and heart rate. Experiments have been performed to standardized methods for measuring psychocardiovascular reactions to be tested under conditions of prolonged weightlessness.

Personnel

1. Dr. Jorge Perez-Cruet, Chief Investigator and Director
2. Mr. Raymond Bannar, Technician II - Assistant in Research
3. Mr. Andrew Calabrese, Technician I - Animal Caretaker
4. Mrs. Patricia Thiess, Secretary

This report was finished 21 December, 1964.

FIGURES 1 to 25

Legend for Figure 1. Multiple blood flows from the carotid, renal, aortic and femoral arteries in acute experiments. Blood pressure was recorded from the femoral artery with a Statham strain-gauge. Paper speed was 25 mm per second.

MULTIPLE BLOOD FLOWS

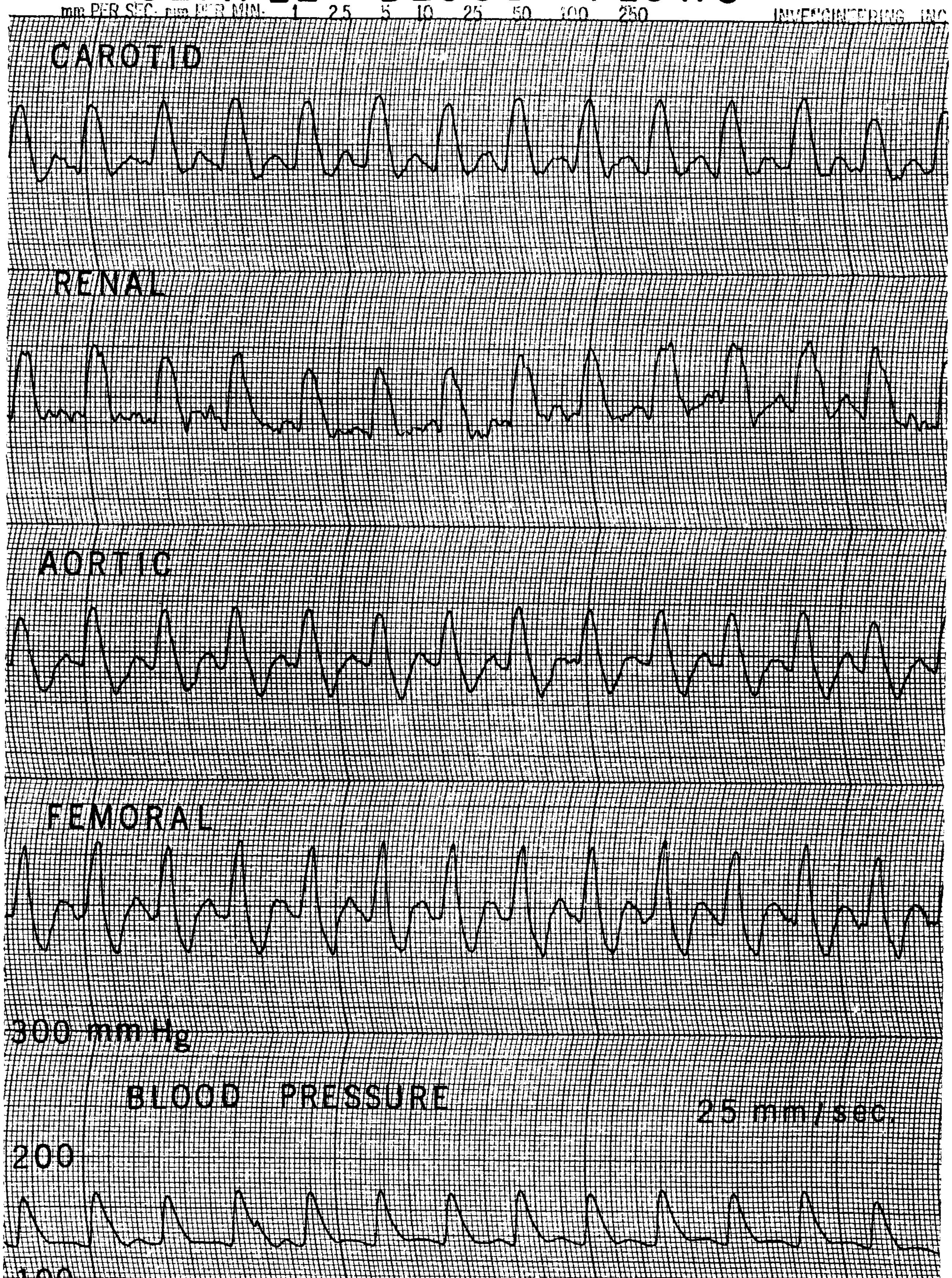


FIG. 1

Legend for Figure 2. Aortic blood flow recorded for a period of 3 weeks in a monkey. The flow-probe was located in the ascending aorta. Part A of the tracings shows aortic blood flow recorded at 250 mm per second. Part B shows pulsatile aortic blood flow in the same animal at a flow speed of 2.5 mm per second. Lower part of the tracings shows the integrated blood flow every 10 seconds.

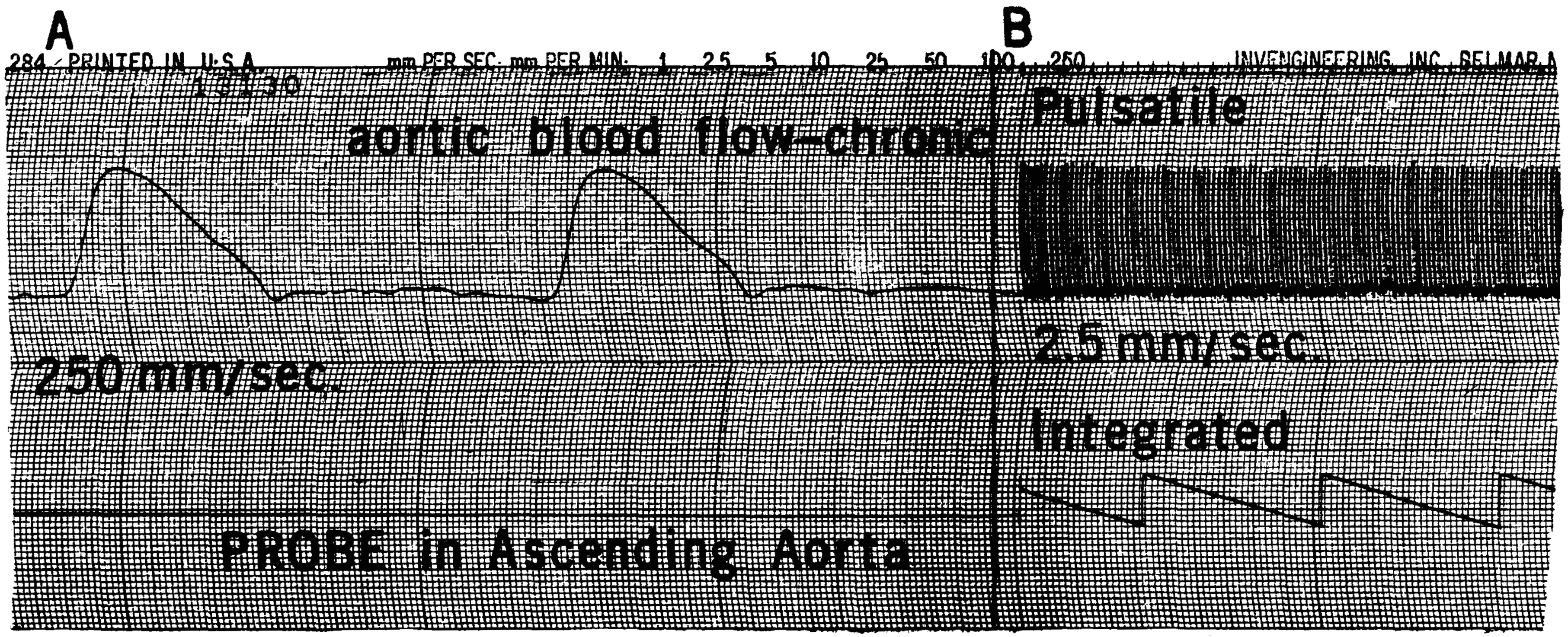

A
B
284 PRINTED IN U.S.A.
13130
mm PER SEC. mm PER MIN. 1 2.5 5 10 25 50 100 250
INVENGINEERING, INC. BELMAR
aortic blood flow-chronic
Pulsatile
250 mm/sec.
2.5 mm/sec.
Integrated
PROBE in Ascending Aorta

FIGURE 2

Legend for Figure 3. Carotid blood flow from a monkey recorded chronically for a month. Paper speed is 25 mm per second.

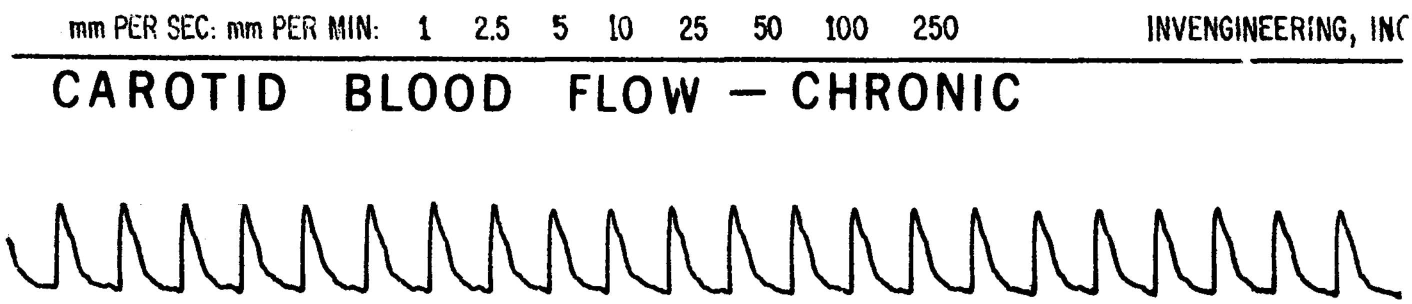

mm PER SEC: mm PER MIN: 1 2.5 5 10 25 50 100 250
INVENGINEERING, INC
CAROTID BLOOD FLOW — CHRONIC

FIG. 3

Legend for Figure 4. Shows femoral and carotid flows in a monkey. Notice the femoral and carotid blood flows show a parallel increase when heart rate increases from 70 beats per minute to 100 beats per minute. Zero baseline represents occlusion zero.

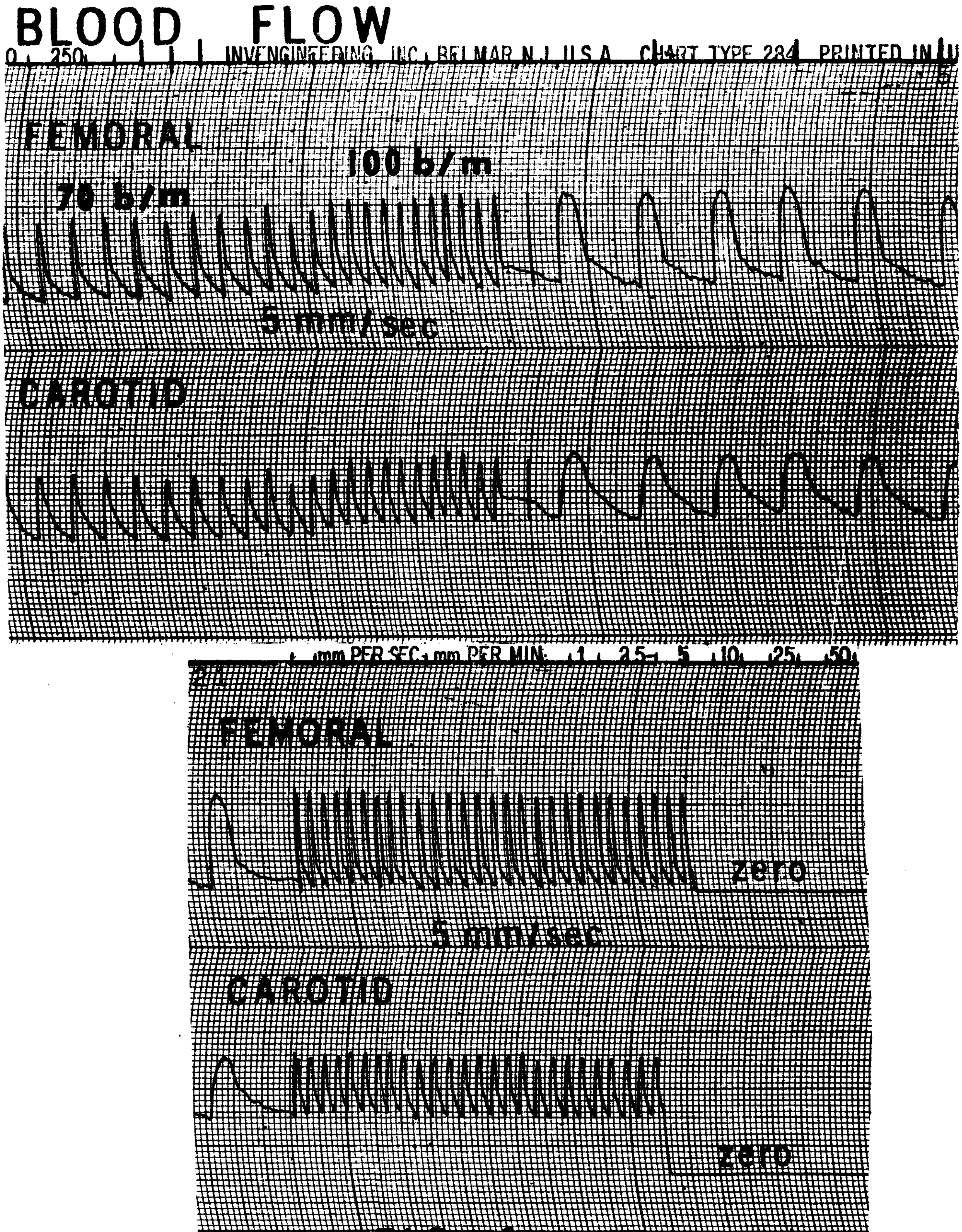

BLOOD FLOW
FEMORAL
100 b/m
70 b/m
5 mm/sec
CAROTID
FEMORAL
zero
5 mm/sec
CAROTID
zero

FIG 4

Legend for Figure 5. Renal blood flow in a dog which had been recorded for a period of a month. Notice direct blood pressure recording from the lower third of the aorta.

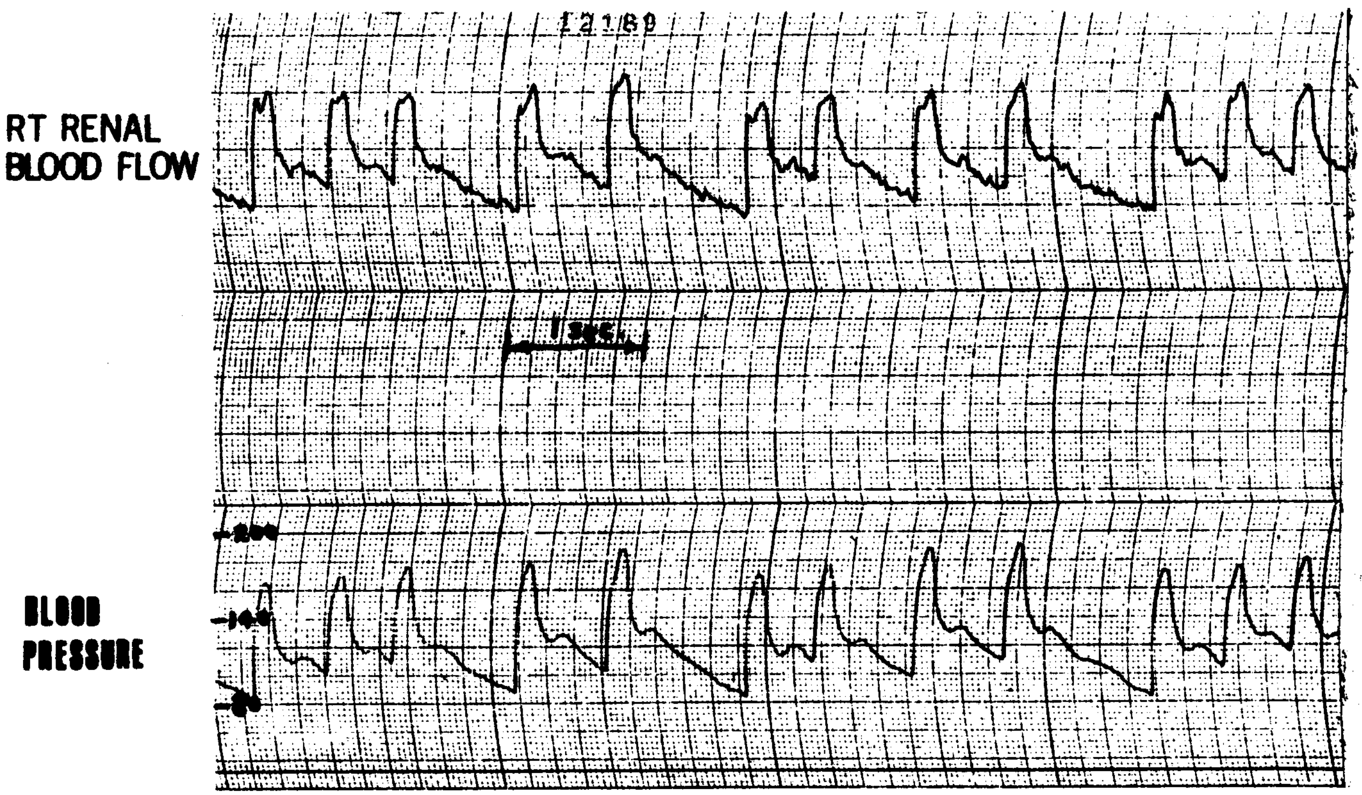


FIG 5

Legend for Figure 6. Aortic blood flow from the ascending aorta which was recorded in a dog for a period of one month. From top to bottom: 1) Pulsatile blood flow from the ascending aorta, 2) Central blood pressure, 3) Peripheral blood pressure, 4) Respiration, 5) Integration of blood flow, 6) Optical plethysmography, 7) Electrocardiogram, and 8) Instantaneous heart rate.

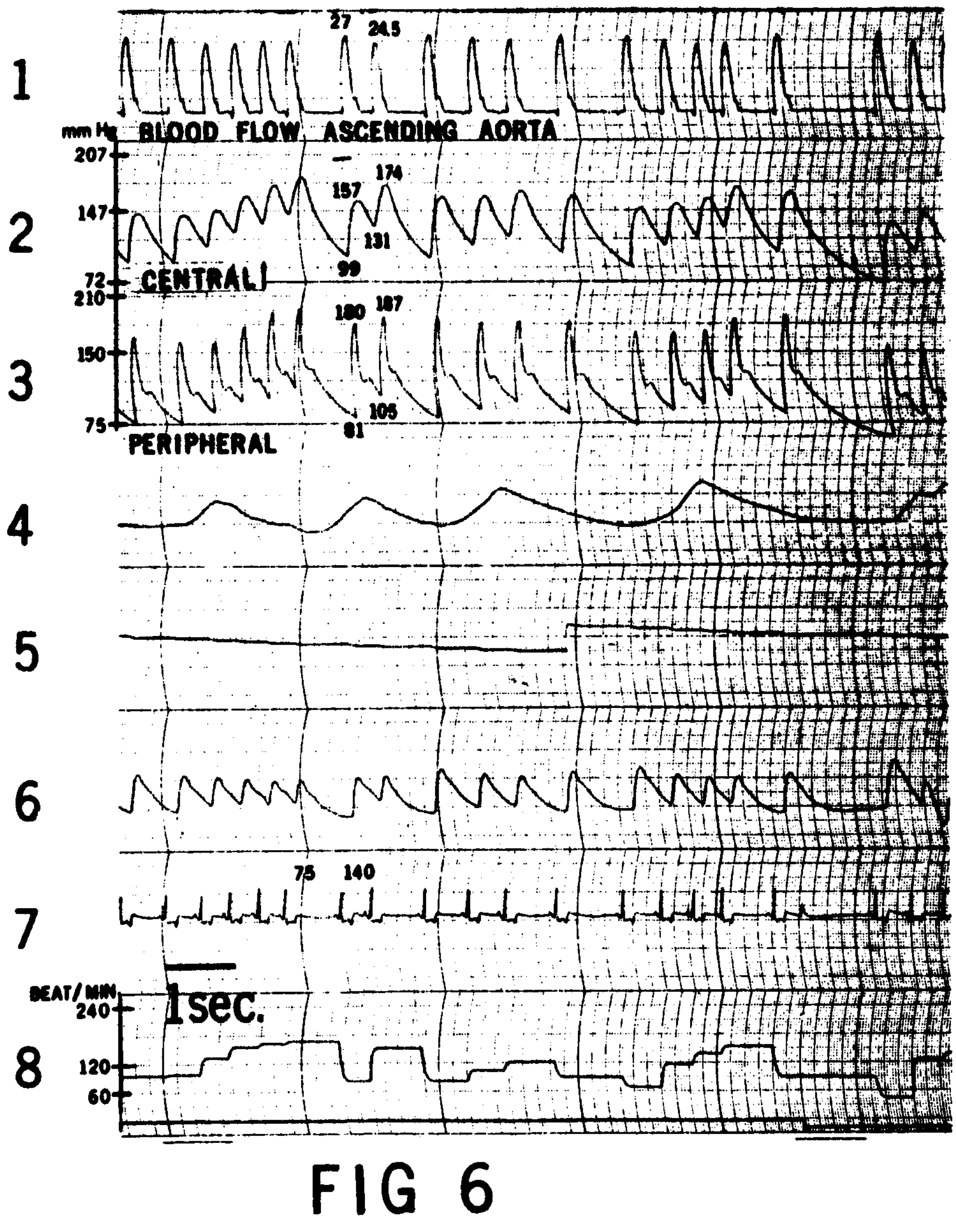

1
BLOOD FLOW ASCENDING AORTA
27
24.5
2
mm Hg
207
147
72
157
174
131
99
CENTRAL
3
210
150
75
180
187
105
81
PERIPHERAL
4
5
6
7
75
140
1sec.
8
BEAT/MIN
240
120
60

FIG 6

Legend for Figure 7. From top to bottom: 1) left kidney blood flow, 2) right kidney blood flow and 3) common carotid blood flow. Tracings below the blood flow represent integrated blood flow. Zero - electrical zero. These blood flows were recorded in one dog for a period of 1 month, simultaneously with measurements of urinary output.

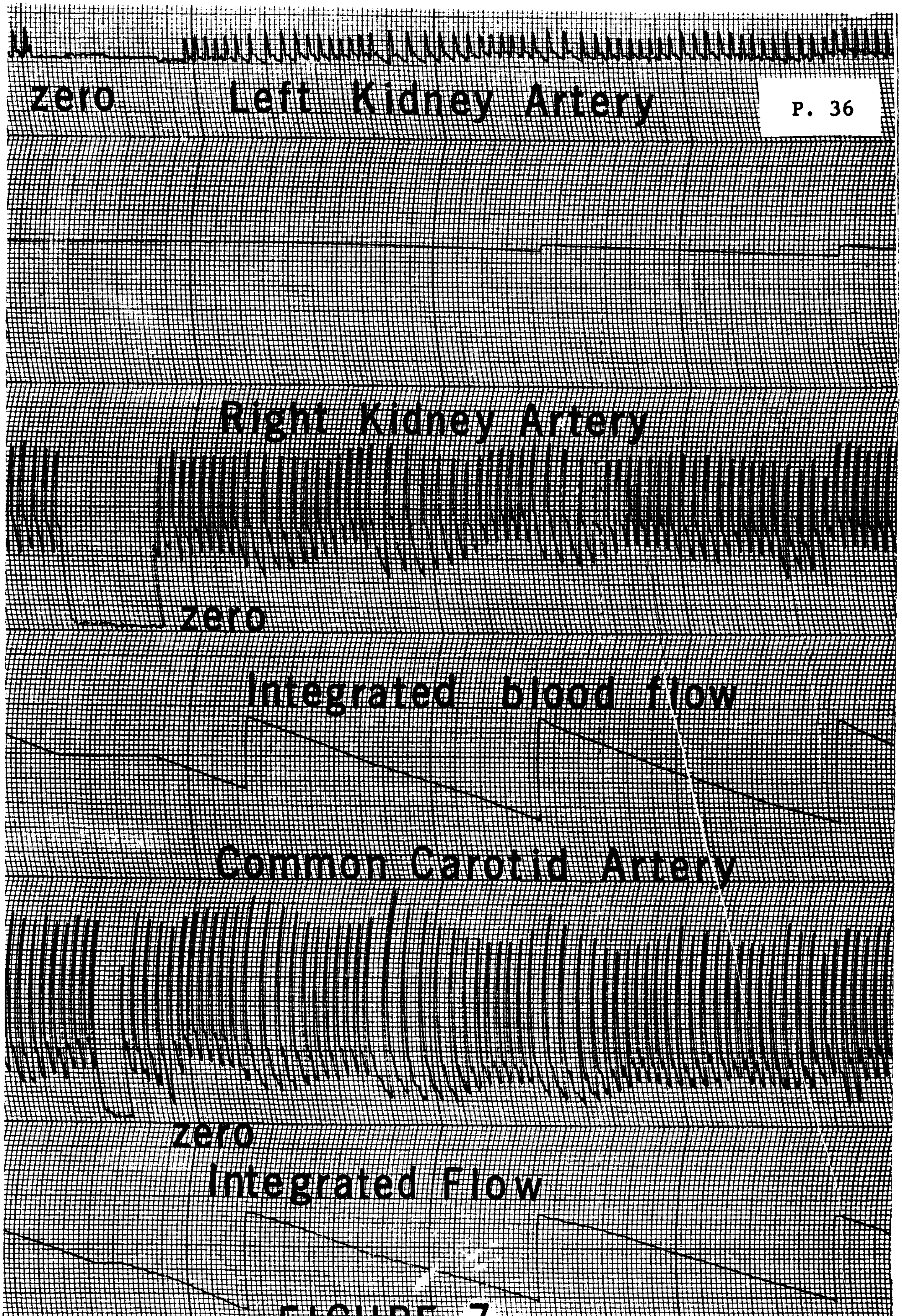

zero
Left Kidney Artery
Right Kidney Artery
zero
Integrated blood flow
Common Carotid Artery
zero
Integrated Flow

FIGURE 7

Legend for Figure 8. Implantation technique of an electromagnetic flow-probe around an artery for measuring chronic blood flows in animals.

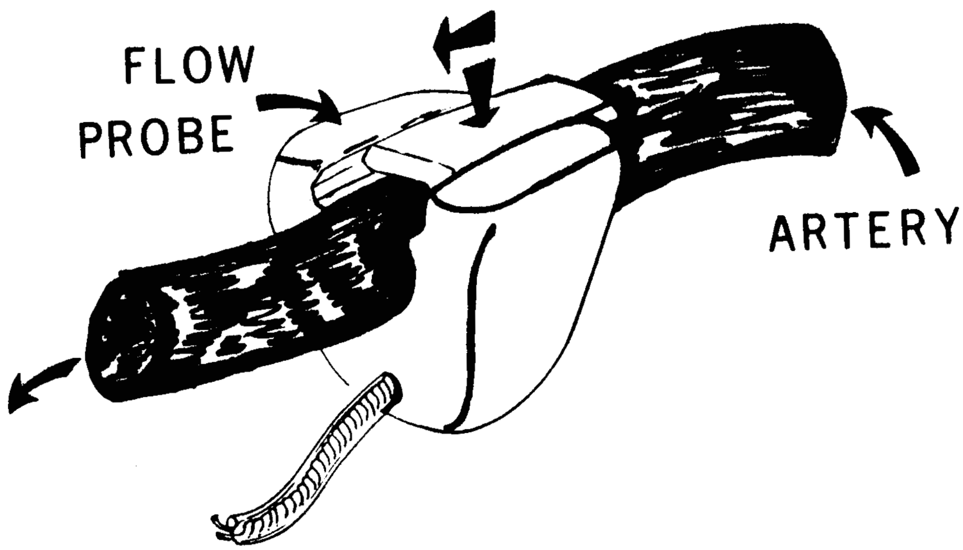


FIG. 8

Legend for Figure 9. Part A shows central blood pressure in a monkey after 2 months. Part B is peripheral blood pressure in the same monkey. Part C is central and peripheral pressures recorded simultaneously in another monkey. Note that the level of blood pressure is higher in the peripheral recording. Pulse pressure is also larger in the peripheral blood pressure.

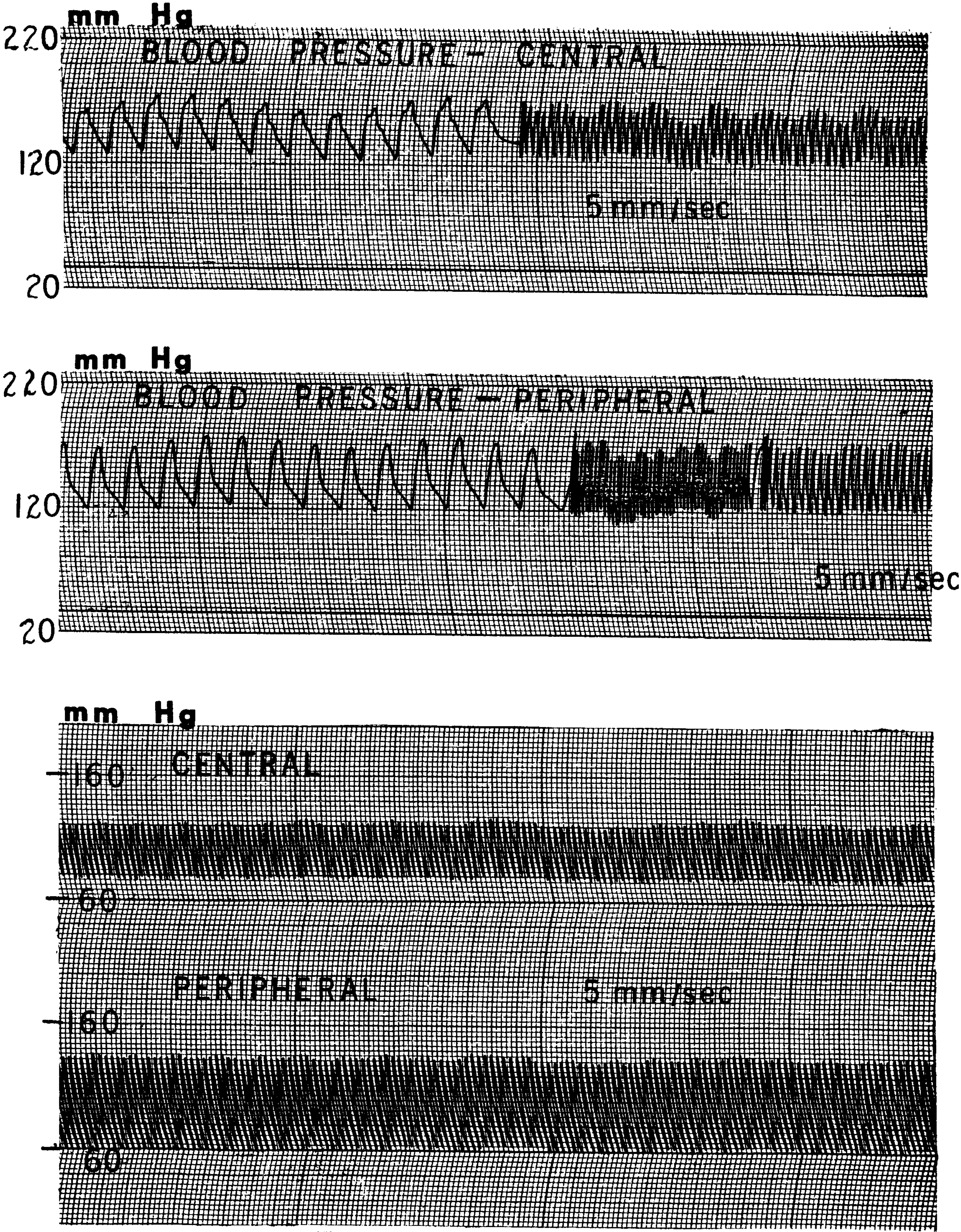

mm Hg
220
BLOOD PRESSURE – CENTRAL
120
5 mm/sec
20
mm Hg
220
BLOOD PRESSURE – PERIPHERAL
120
5 mm/sec
20
mm Hg
160
CENTRAL
60
PERIPHERAL
5 mm/sec
160
60

FIG 9

Legend for Figure 10. Changes in the blood pressure to an inhibitory tone (512) and to an excitatory tone (256). Tone 256 was always reinforced with orange juice (see arrow). Notice the anticipatory change in blood pressure during tone 256 (+ CS). The orange juice produces a change in blood pressure of about 30 mm Hg. Note that there is no marked change with the inhibitory tone. Blood pressure was recorded in the mm Hg. Paper speed was 5 mm per second.

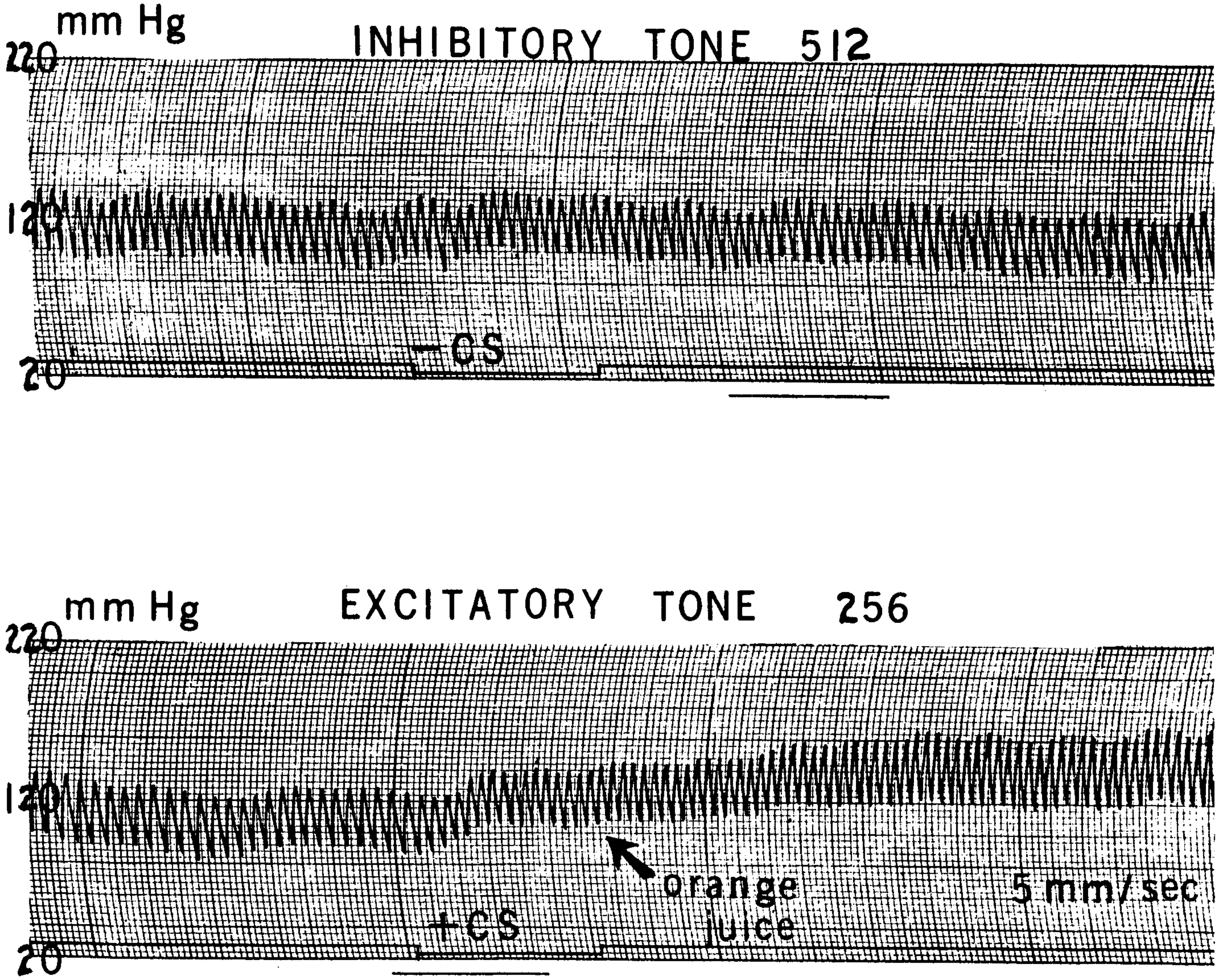

mm Hg
INHIBITORY TONE 512
220
120
20
-CS
mm Hg
EXCITATORY TONE 256
220
120
20
+CS
orange juice
5 mm/sec

FIG 10

Legend for Figure 11. Baseline blood pressures for 18 days. Notice that the blood pressure stabilized after a week. Peripheral and central blood are: 1) peripheral systolic, 2) peripheral diastolic, 3) central systolic, 4) central diastolic.

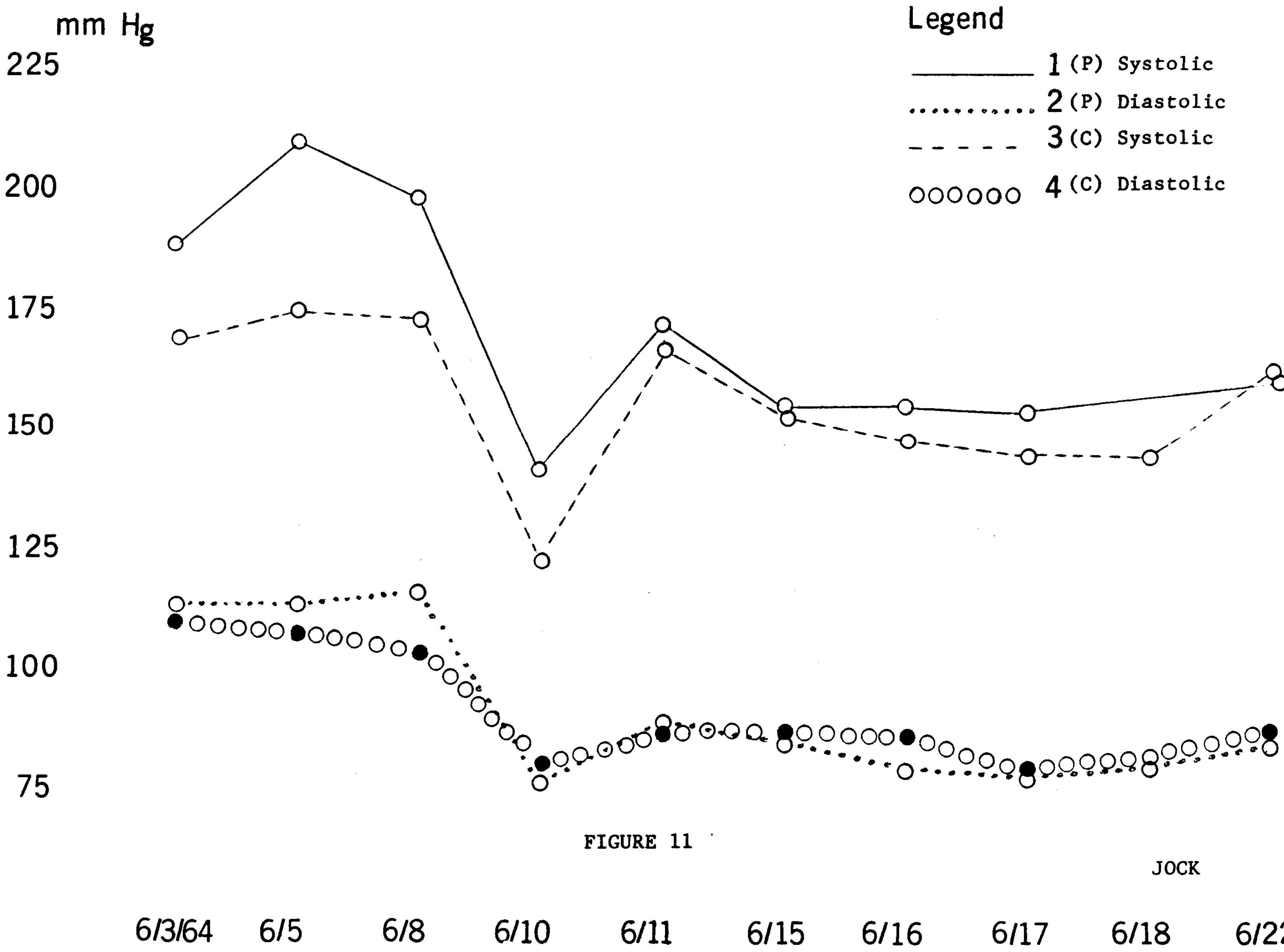

mm Hg
225
200
175
150
125
100
75
Legend
1 (P) Systolic
2 (P) Diastolic
3 (C) Systolic
4 (C) Diastolic
JOCK
6/3/64
6/5
6/8
6/10
6/11
6/15
6/16
6/17
6/18
6/22

FIGURE 11

Legend for Figure 12. Baseline blood pressures in another monkey for 3 weeks. Notice that the level of the blood pressure increases after 11 days. 1) peripheral systolic, 2) peripheral diastolic, 3) central systolic, 4) central diastolic.

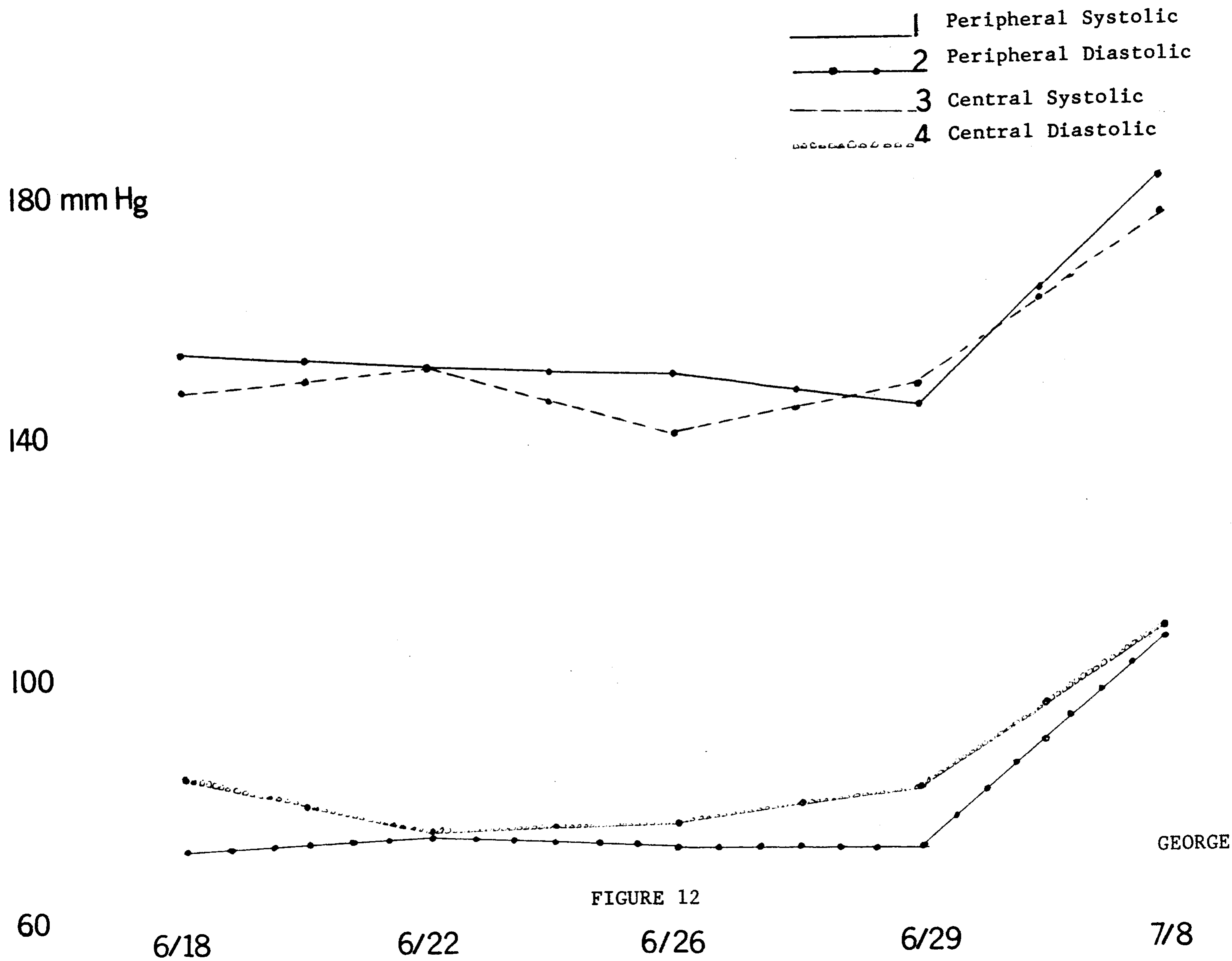

1 Peripheral Systolic
2 Peripheral Diastolic
3 Central Systolic
4 Central Diastolic
180 mm Hg
140
100
60
6/18
6/22
6/26
6/29
7/8
GEORGE

FIGURE 12

Legend for Figure 13. Shows changes in heart rate and blood pressure during complete chronic restrain for 14 days. This experiment showed that complete restraint did not affect seriously the cardiovascular variable.

RECORDINGS DURING COMPLETE CHRONIC RESTRAINT

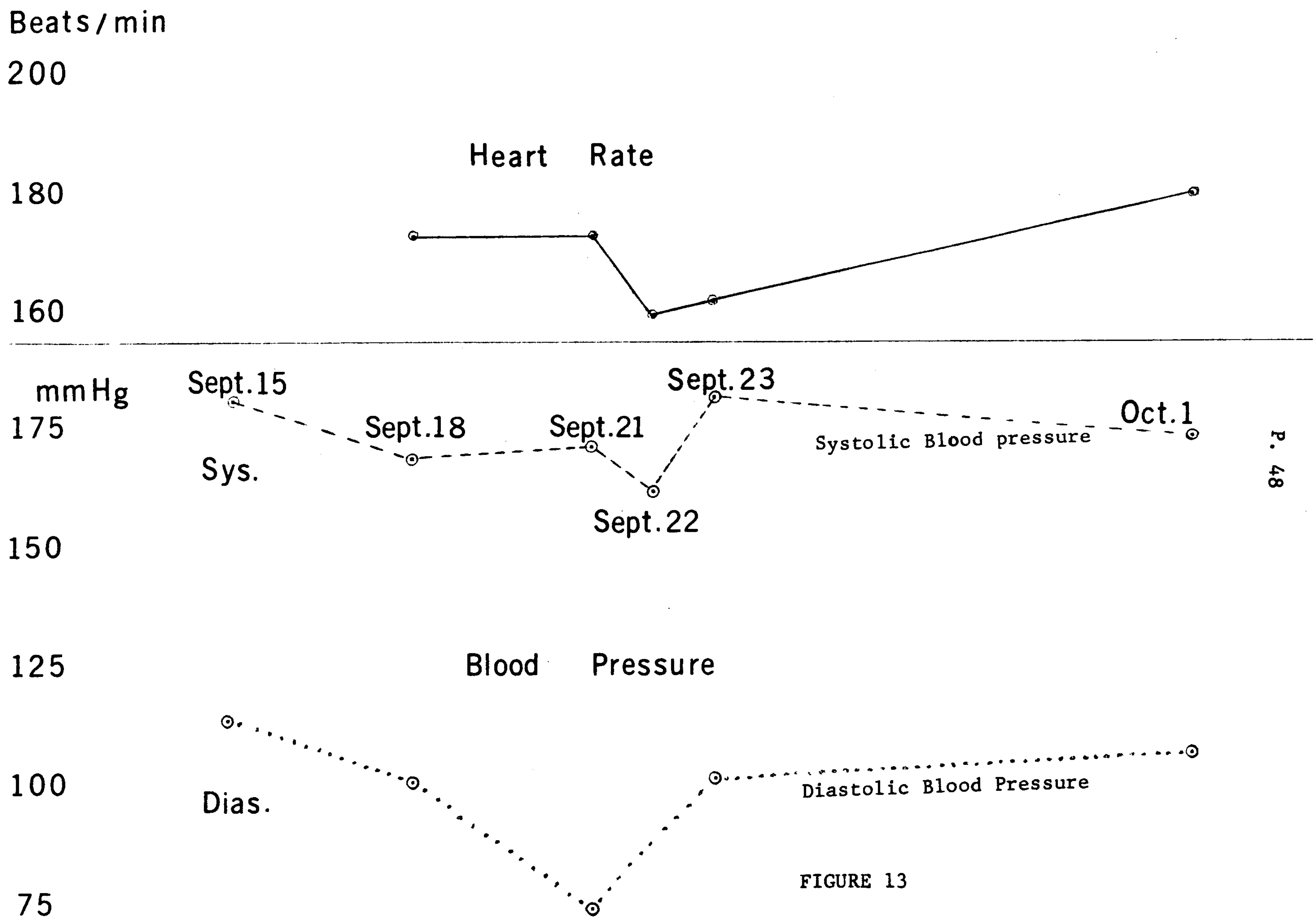


FIGURE 13

Legend for Figure 14. Standard recording of electrocardiogram using implanted electrodes. A standardization 1 mv./cm. Part A shows electrocardiograms in leads 1, 2 and 3. Part B shows electrocardiograms in another monkey in lead 2 at paper speed of 25 to 50 mm per sec.

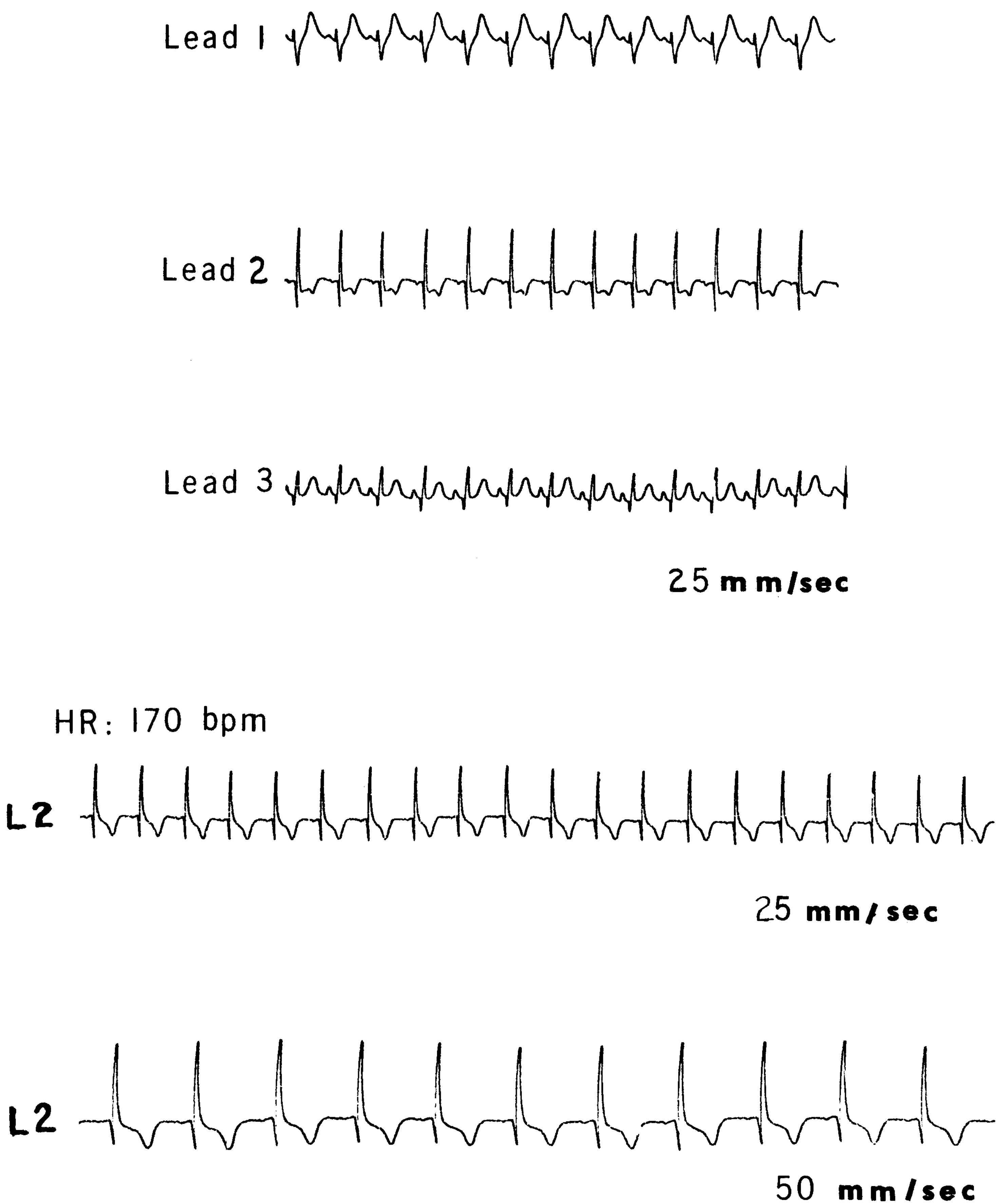


FIG 14

Legend for Figure 15. Show the effect of electric shock on the electrocardiogram and heart rate. Notice that there was a temporary bradycardia during the electric shock, but the heart rate increased from 170 bpm to 195 bpm immediately after the electric shock. Tracings A, B and C are continous. Paper speed was 25 mm per second.

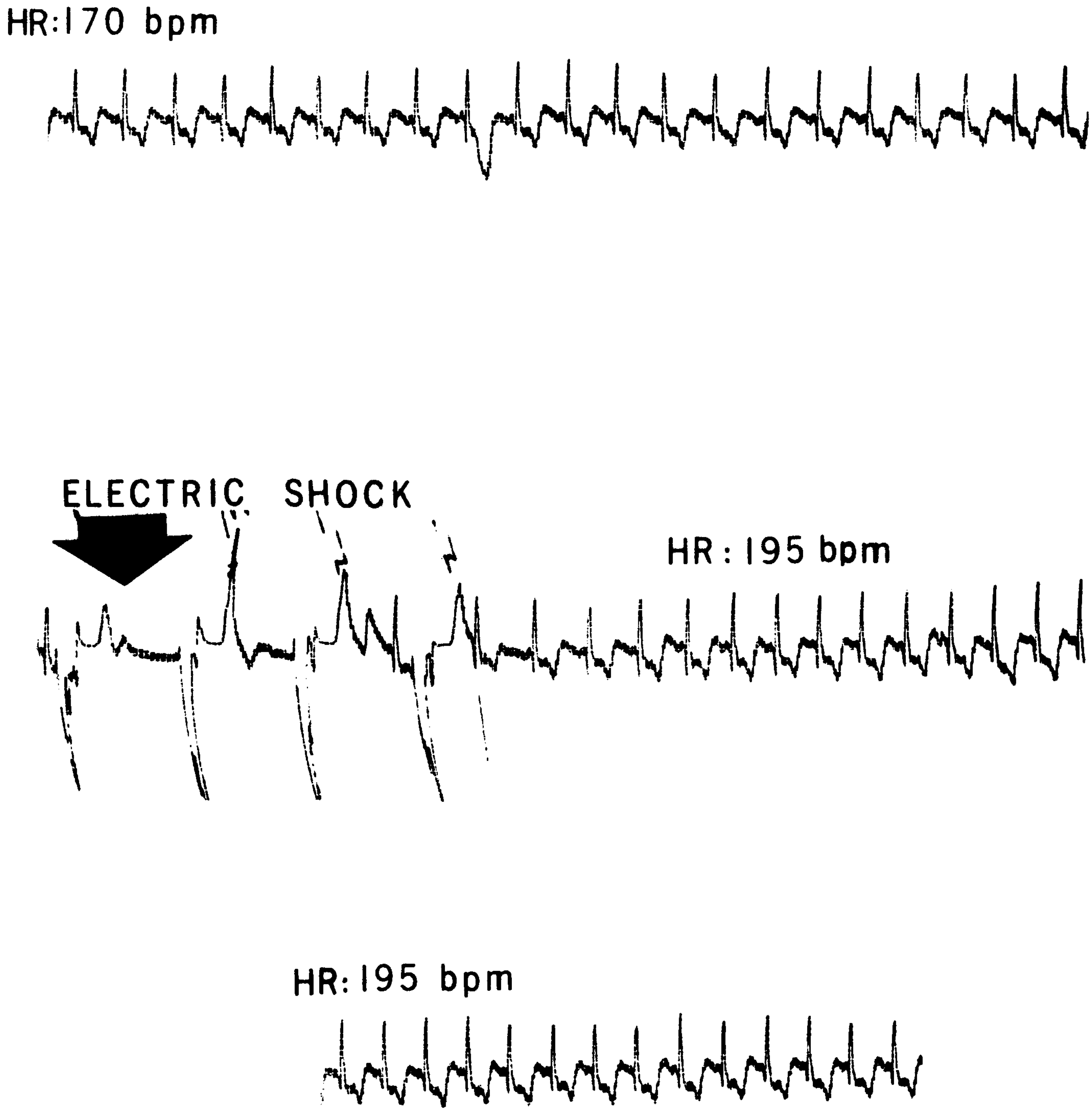


FIG 15

Legend for Figure 16. Plans and organization of sound attenuated booths for "simulated" space flight conditions. A: sound-attenuated booth. B: Offner recorder for monitoring variables. C: programming and feeding devices. Room will be provided with controlled 12 hour-day periods and 12 hour-night periods automatically.

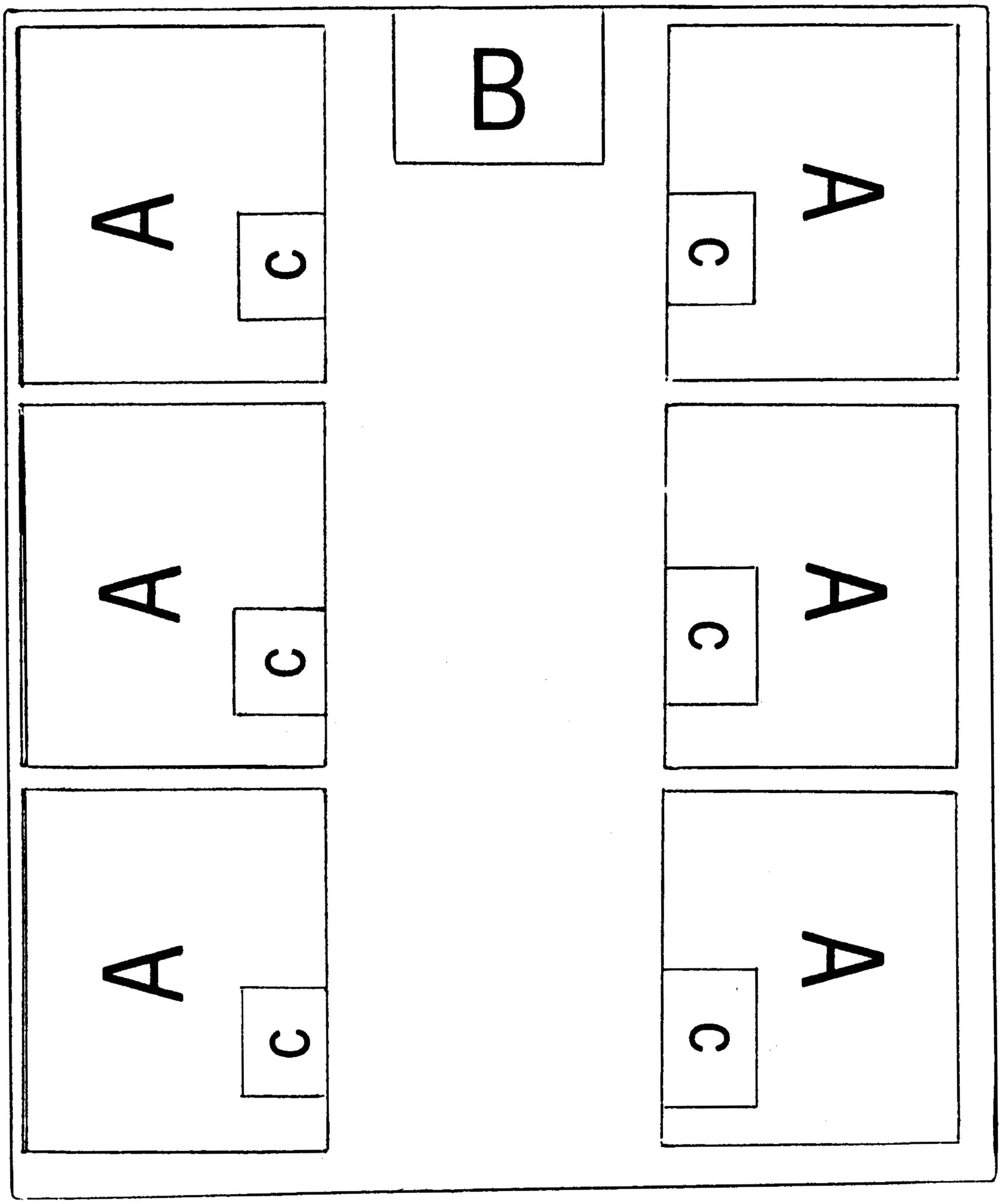
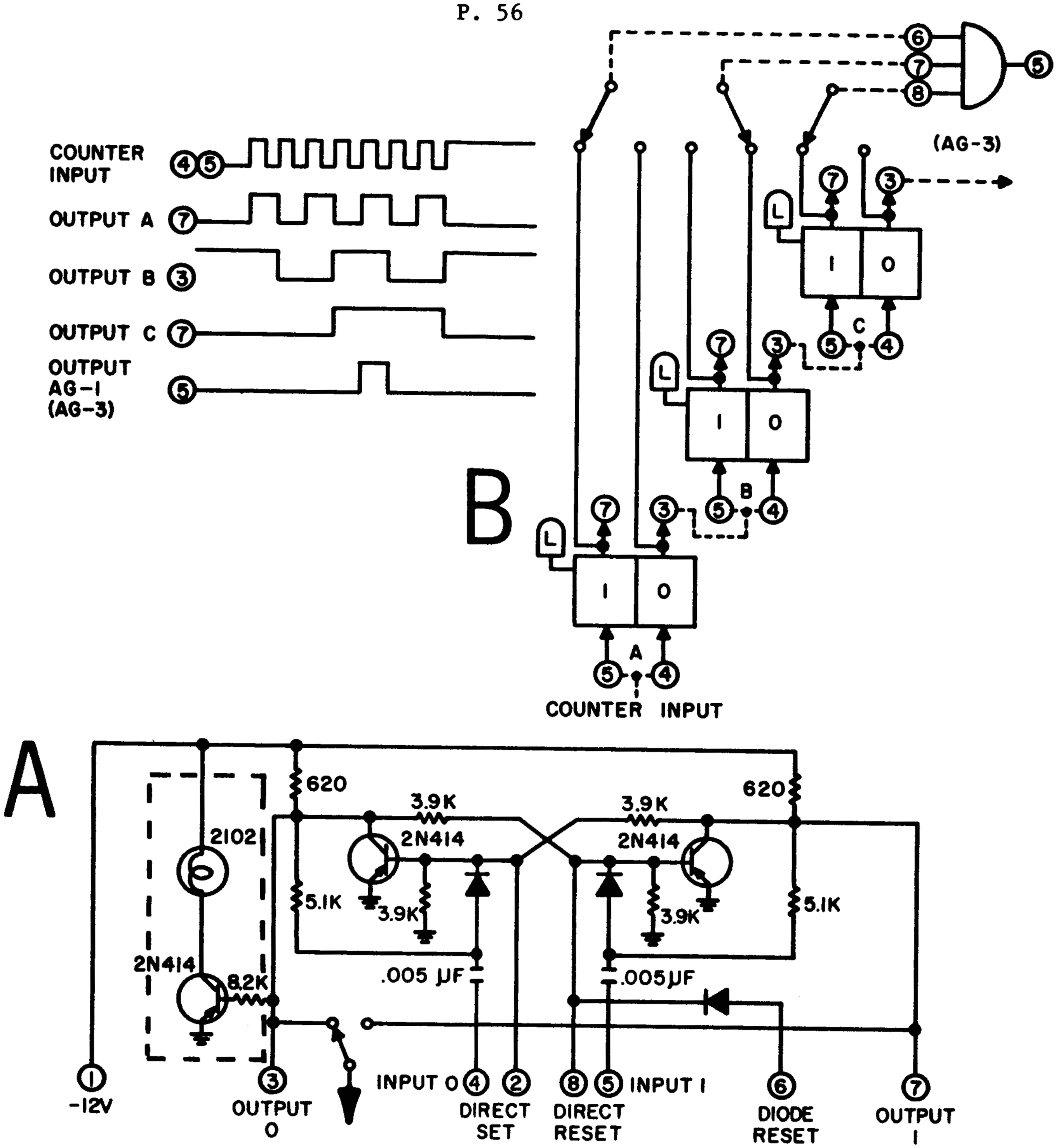


FIG. 16

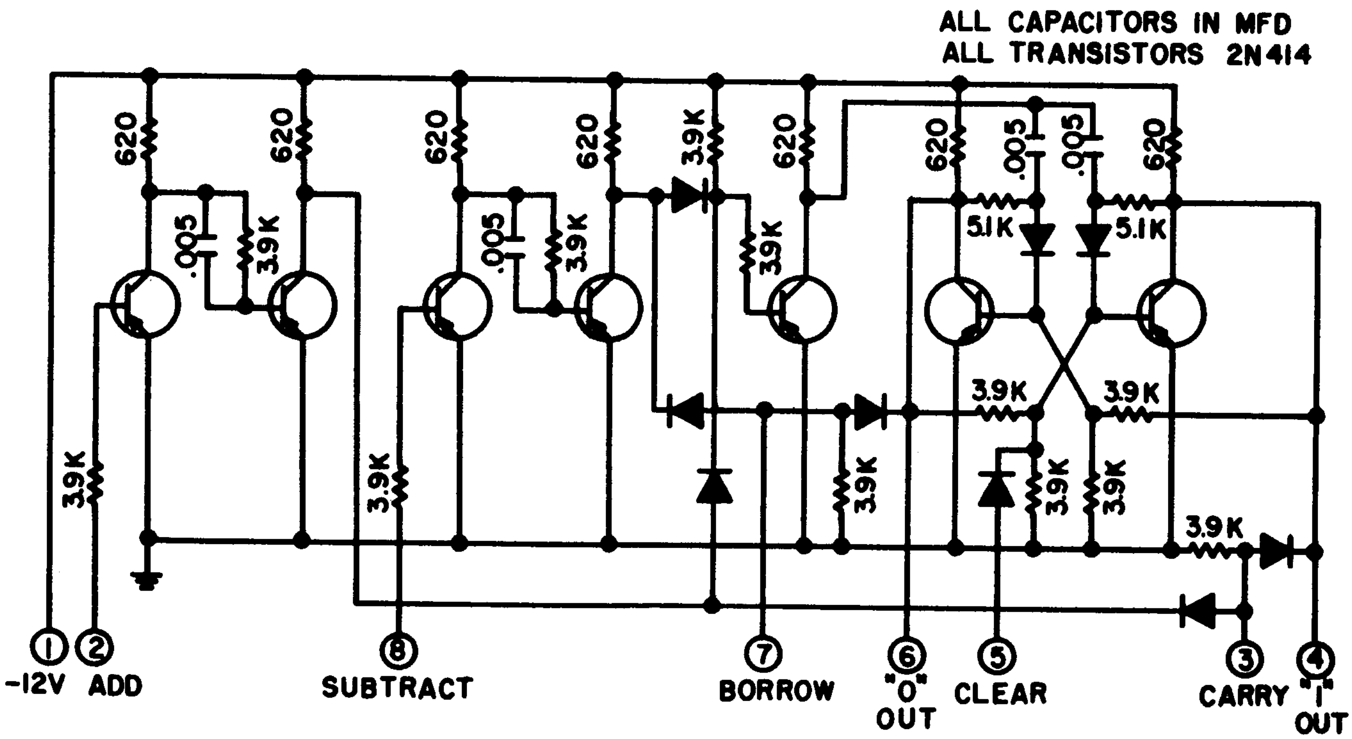
Legend for Figure 17. Circuit diagram of a flip-flop (A) and binary counter assembly (B).



FLIP-FLOP
WITH OUTPUT SELECTION
AND INDICATOR
FF-S / FF-6

FIG. 17

Legend for Figure 18. Circuit diagram of a single stage Add-Subtract Counter.



SINGLE STAGE
ADD-SUB-COUNTER
UD-1

FIG. 18

Legend for Figure 19. Techniques for preparing arterial catheters. A: plain polyvinyl tubing. B: two polyvinyl rings which have an inside diameter (I.D.) of the exact size as the outside diameter (O.D.) of the tubing. C: rings inserted and fixed with monomer adhesive to the polyvinyl tubing. D: stainless-steel plug used to occlude the catheters at the opposite end. The end of the catheter is always connected to a Statham strain-gauge P23De when measuring blood pressures.

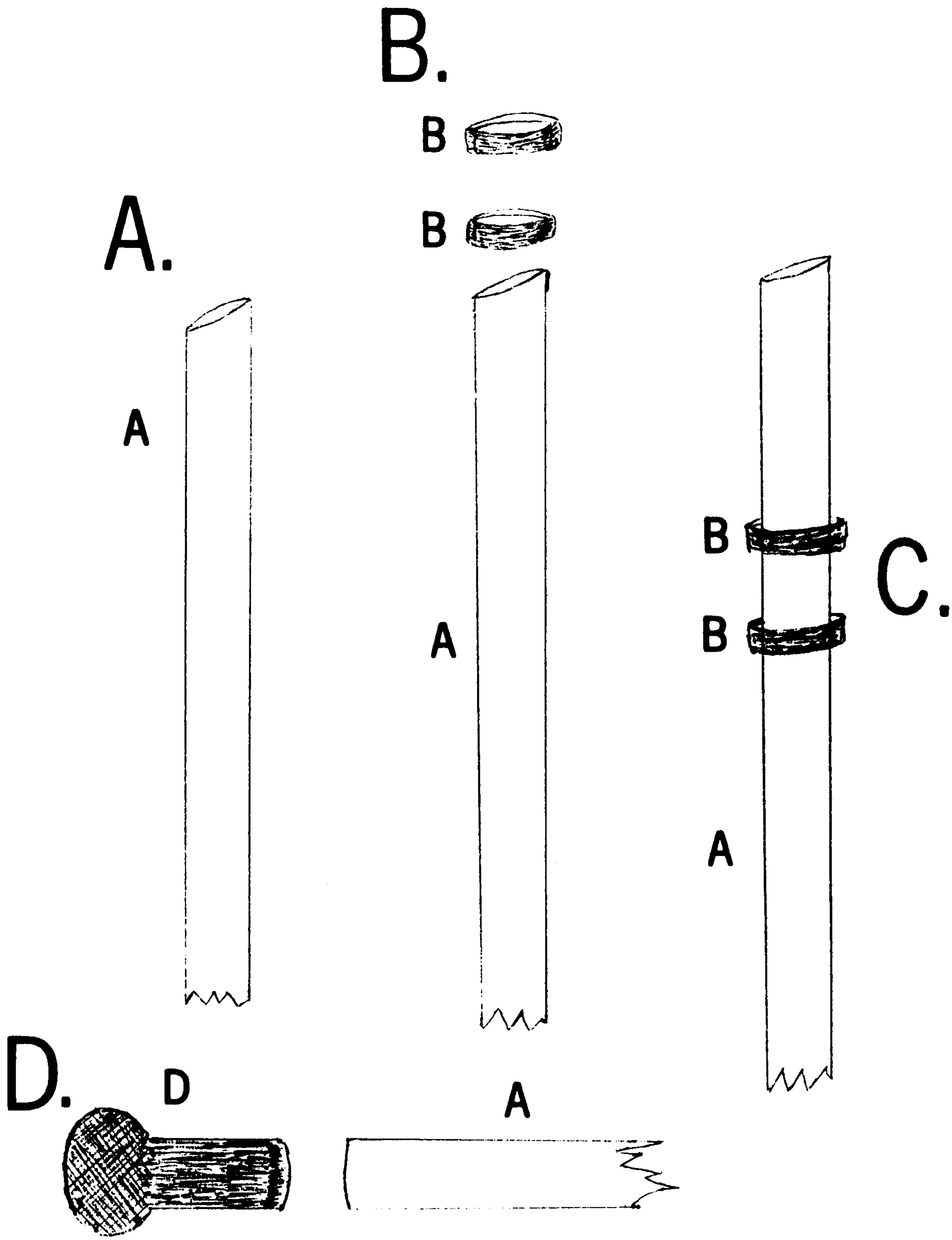


FIG. 19

Legend for Figure 20. Effect of tones 256 and 512 on blood pressure during control sessions before conditioning. The duration of the tones was 6 seconds with an inter-trail interval of 2 to 3 minutes. Notice that the tones do not produce any marked changes in blood pressure. Ordinate is in mm Hg and abscissa in seconds.

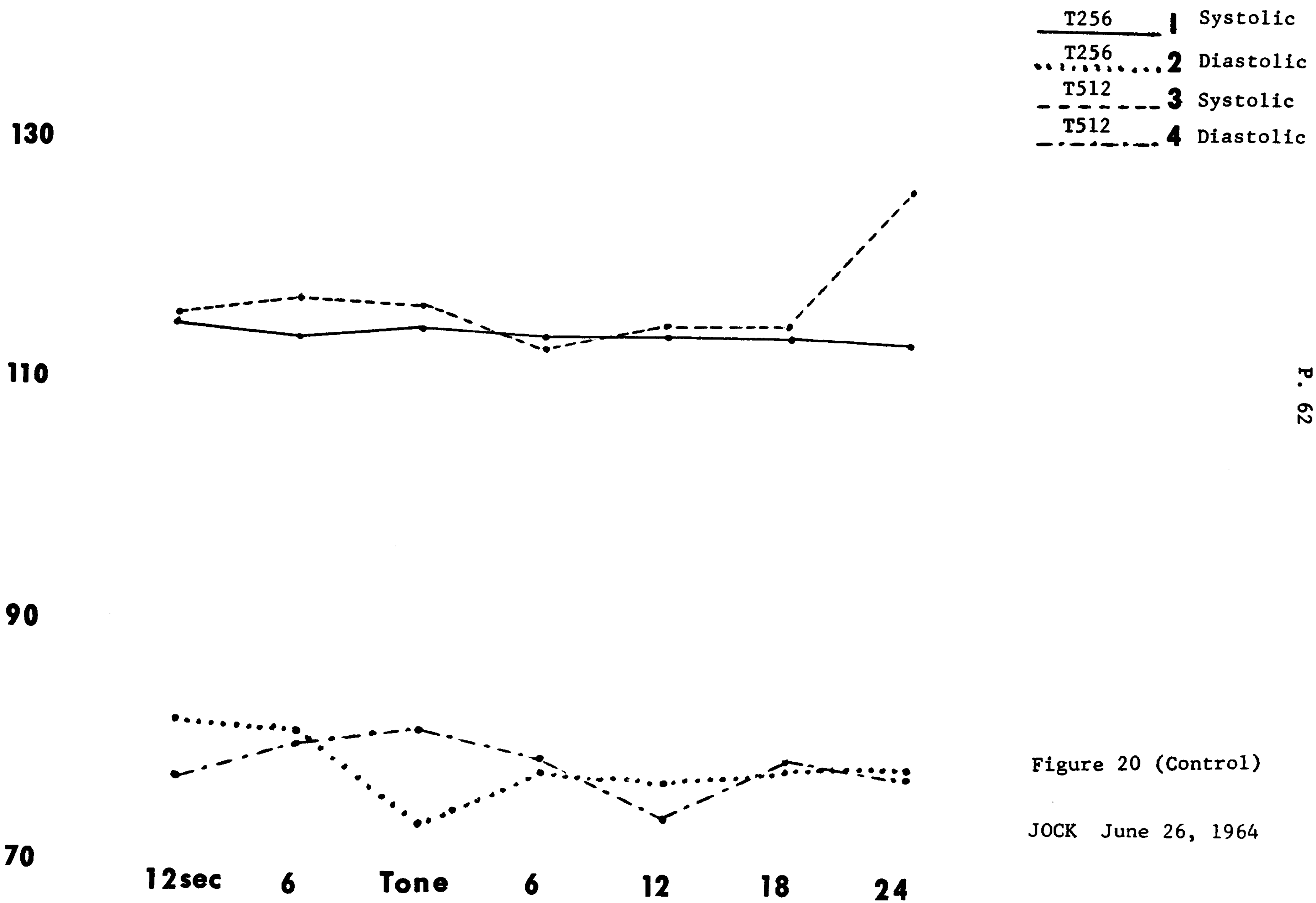


Figure 20 (Control)

JOCK June 26, 1964

Legend for Figure 21. Initial phases of conditioning. Note that tone 256, which is always reinforced with orange juice, produces a slight conditional change in blood pressure. Note also the marked changes (unconditional reflex) in blood pressure which were produced 12 to 24 seconds after the tone by the juice (unconditional stimulus). There is no change in blood pressure to the inhibitory tone (512).

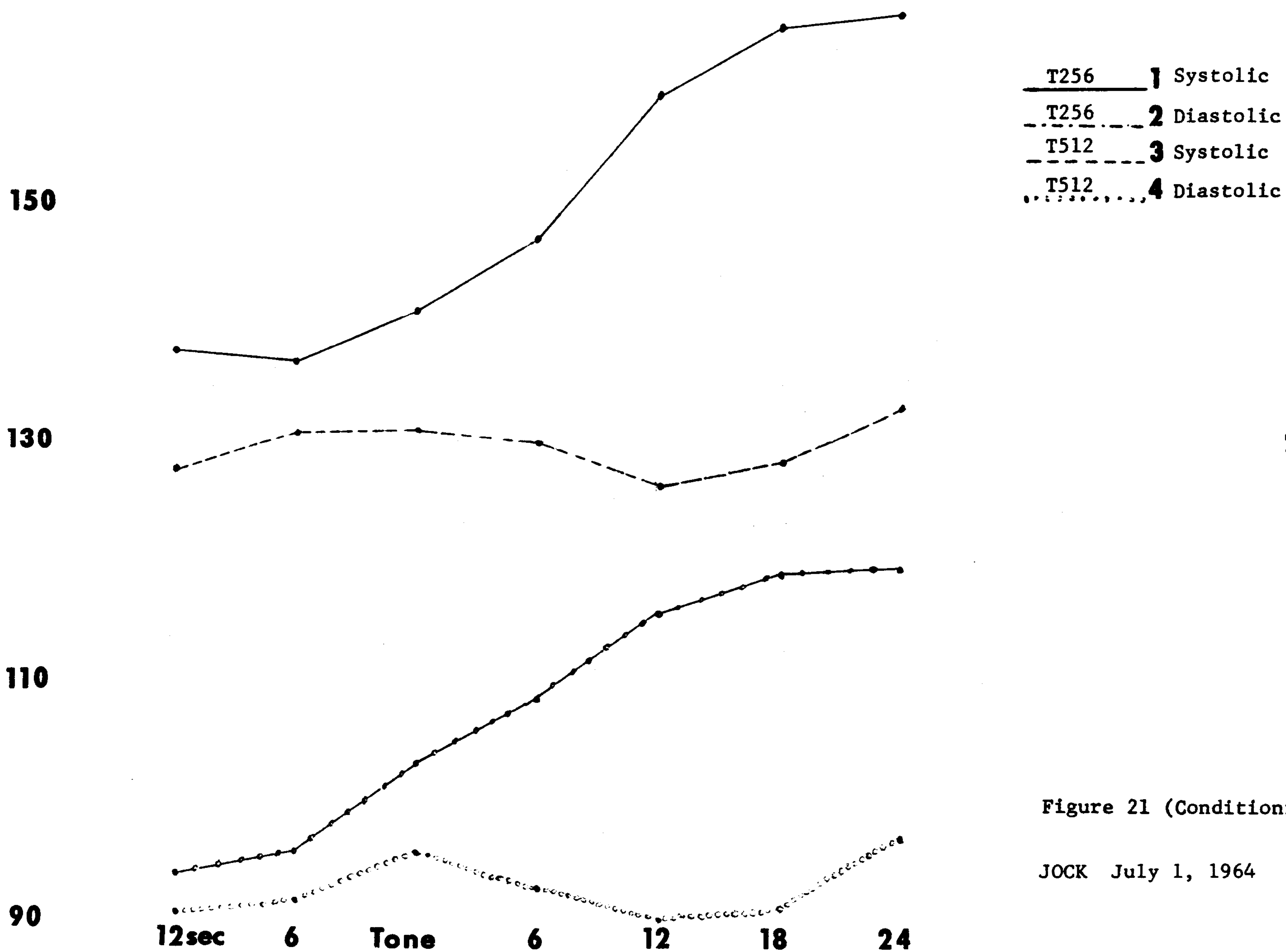


Figure 21 (Conditioning)

JOCK July 1, 1964

Legend for Figure 22. Tracing from experimental session showing unconditional changes produced by the orange juice and adaptation of blood-pressure conditional reflexes.

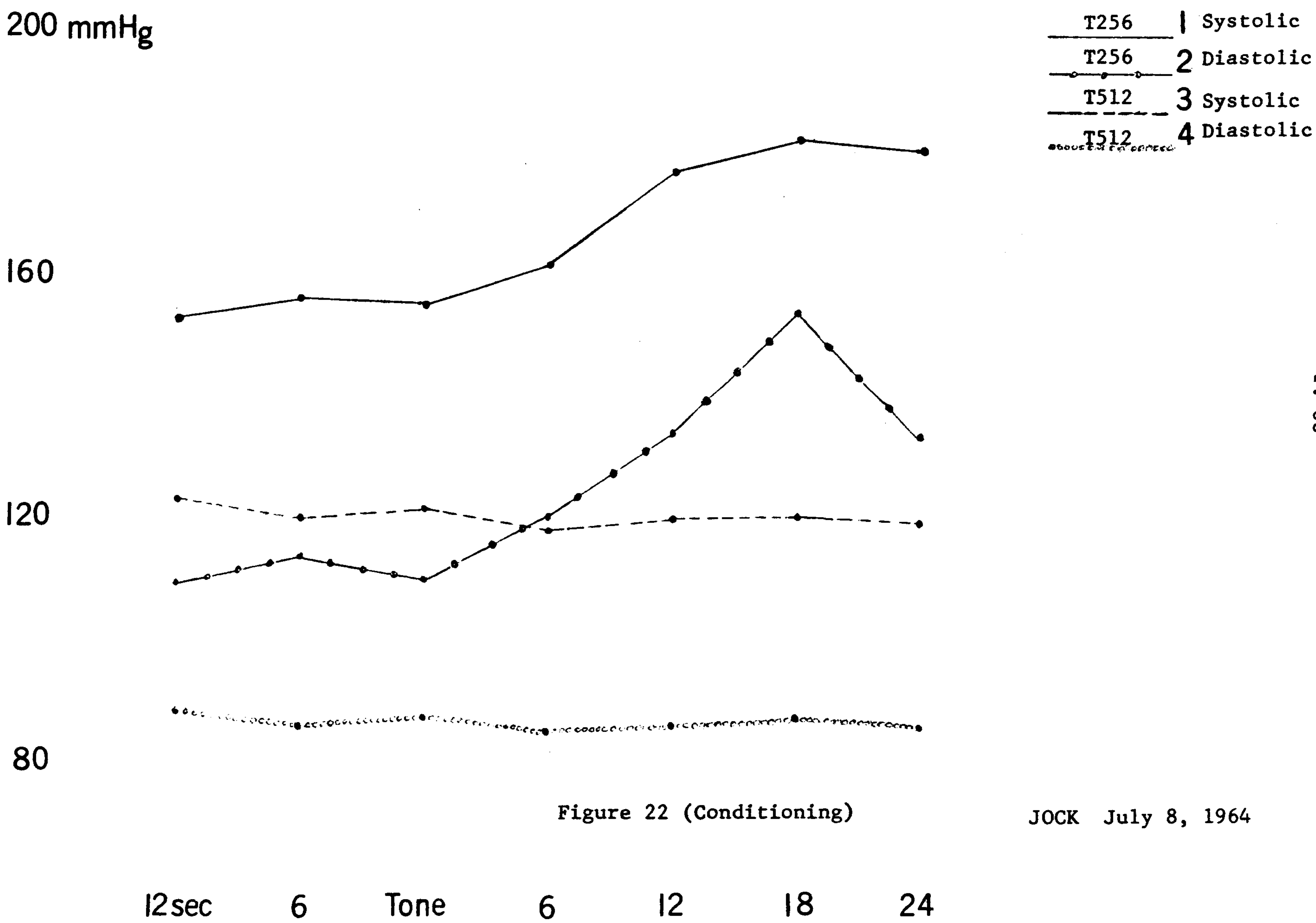


Figure 22 (Conditioning)

JOCK July 8, 1964

Legend for Figure 23. Tracing showing slight blood-pressure conditional reflexes two weeks after experimental session shown in Figure 22.

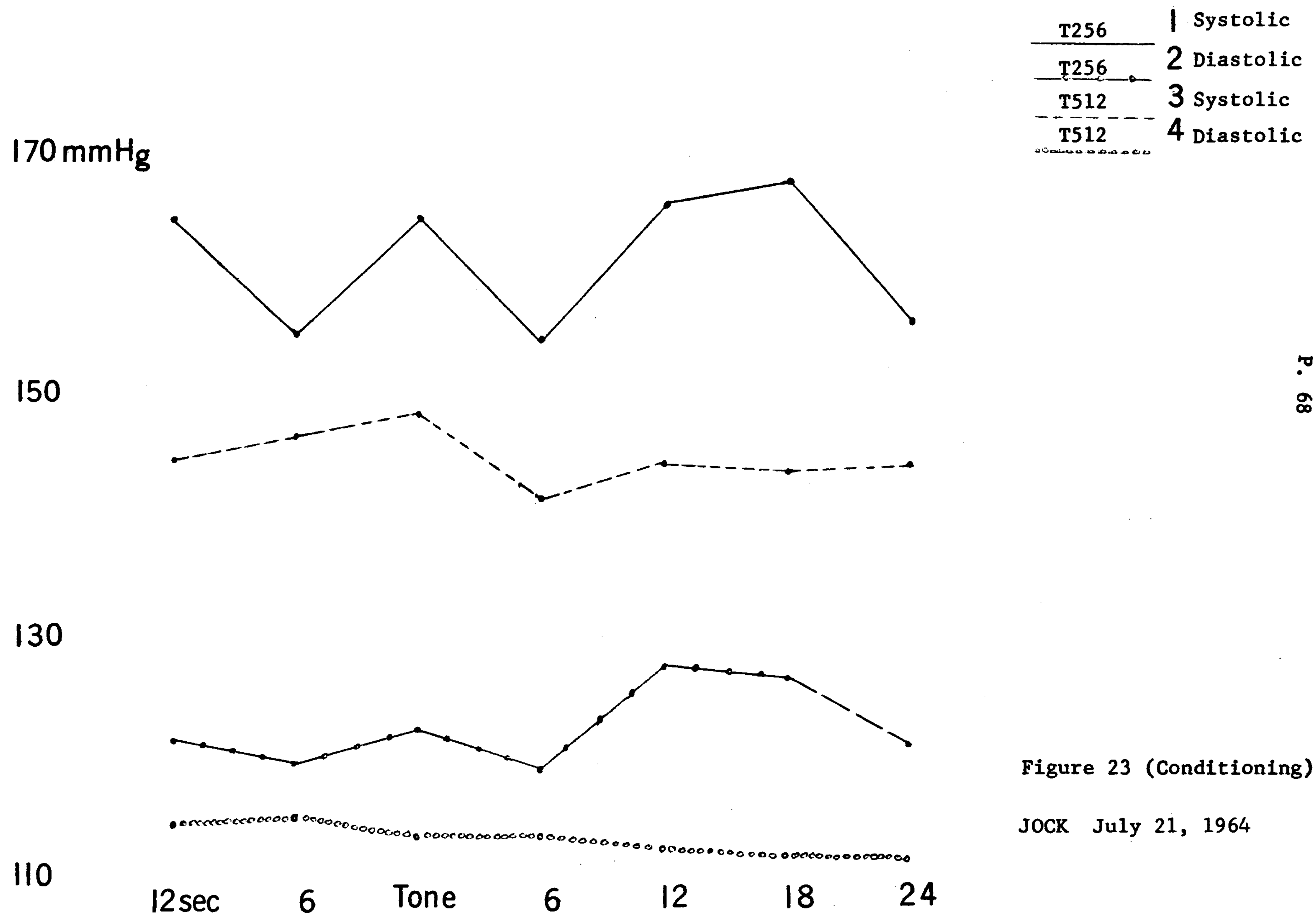


Figure 23 (Conditioning)

JOCK July 21, 1964

Legend for Figure 24. Undifferentiated blood-pressure conditional reflexes to tones 256 and 512. Note that the unconditional reflex to orange juice occurs 6 seconds after tone 256.

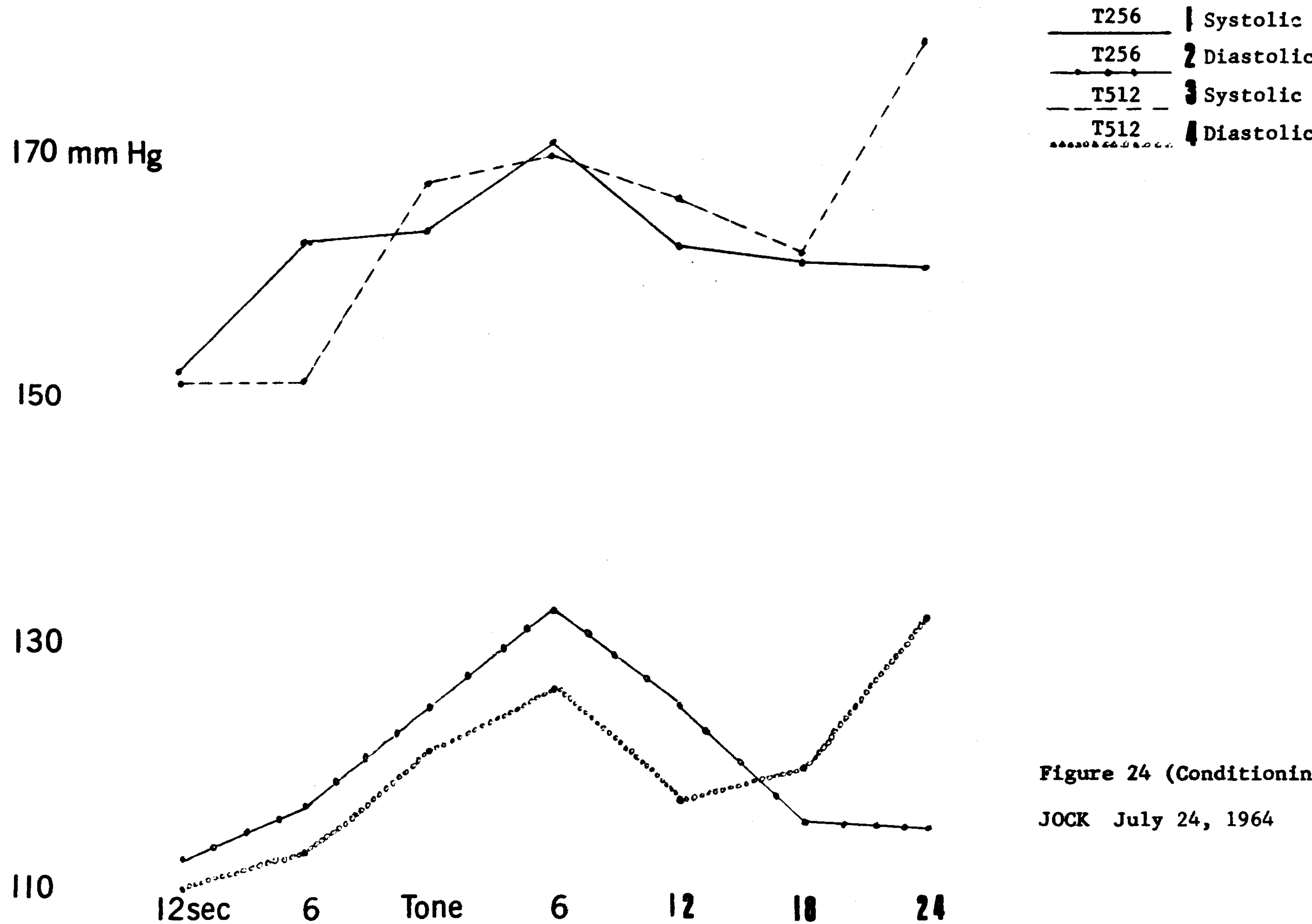


Figure 24 (Conditioning)

JOCK July 24, 1964

Legend for Figure 25. This figure illustrates changes in blood pressure during extinction to a tone that has previously been reinforced with orange juice. Notice that the blood pressure increases during tone 256 (excitatory) but it does not change to tone 512 (inhibitory) which has never been reinforced with the juice.

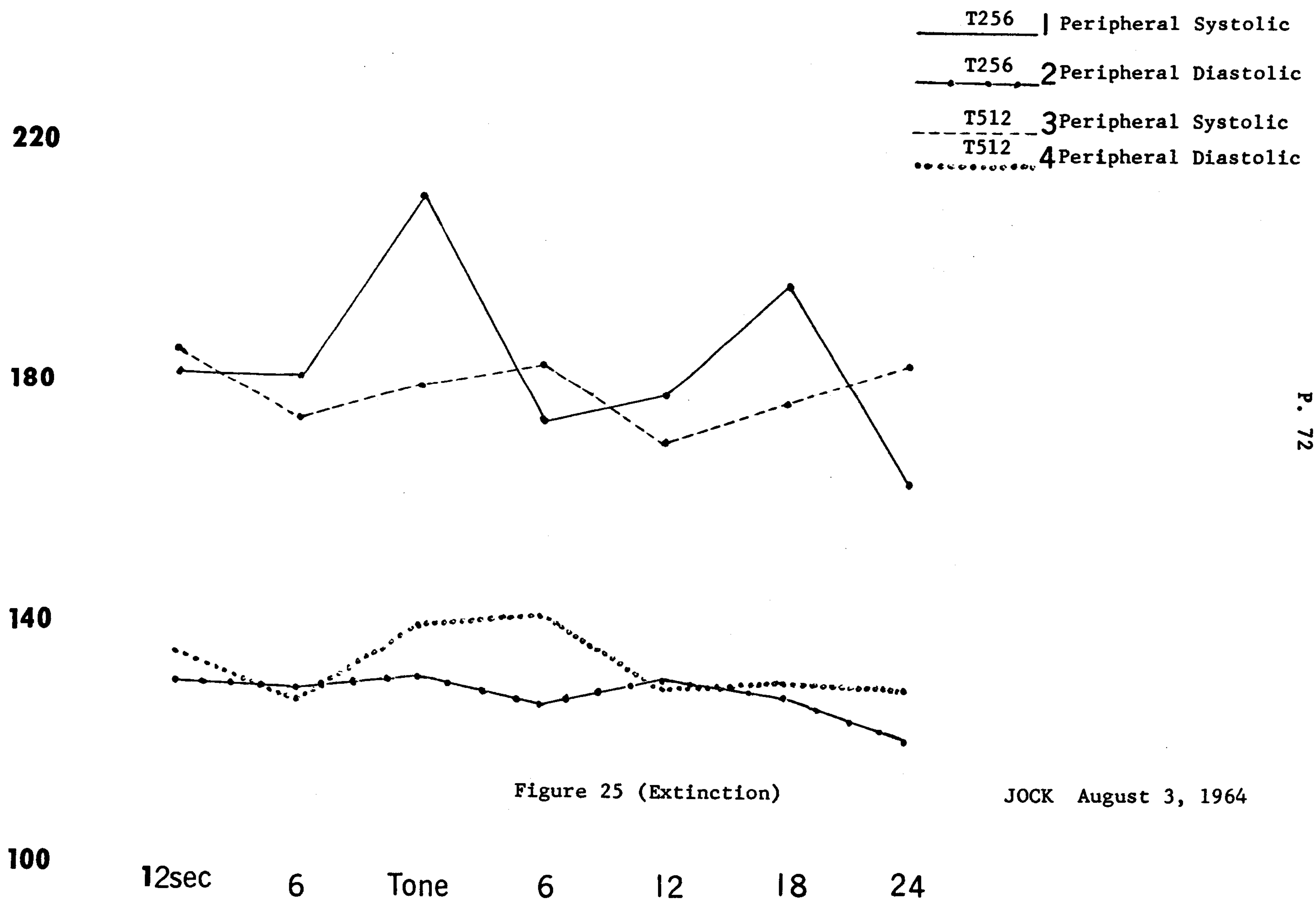
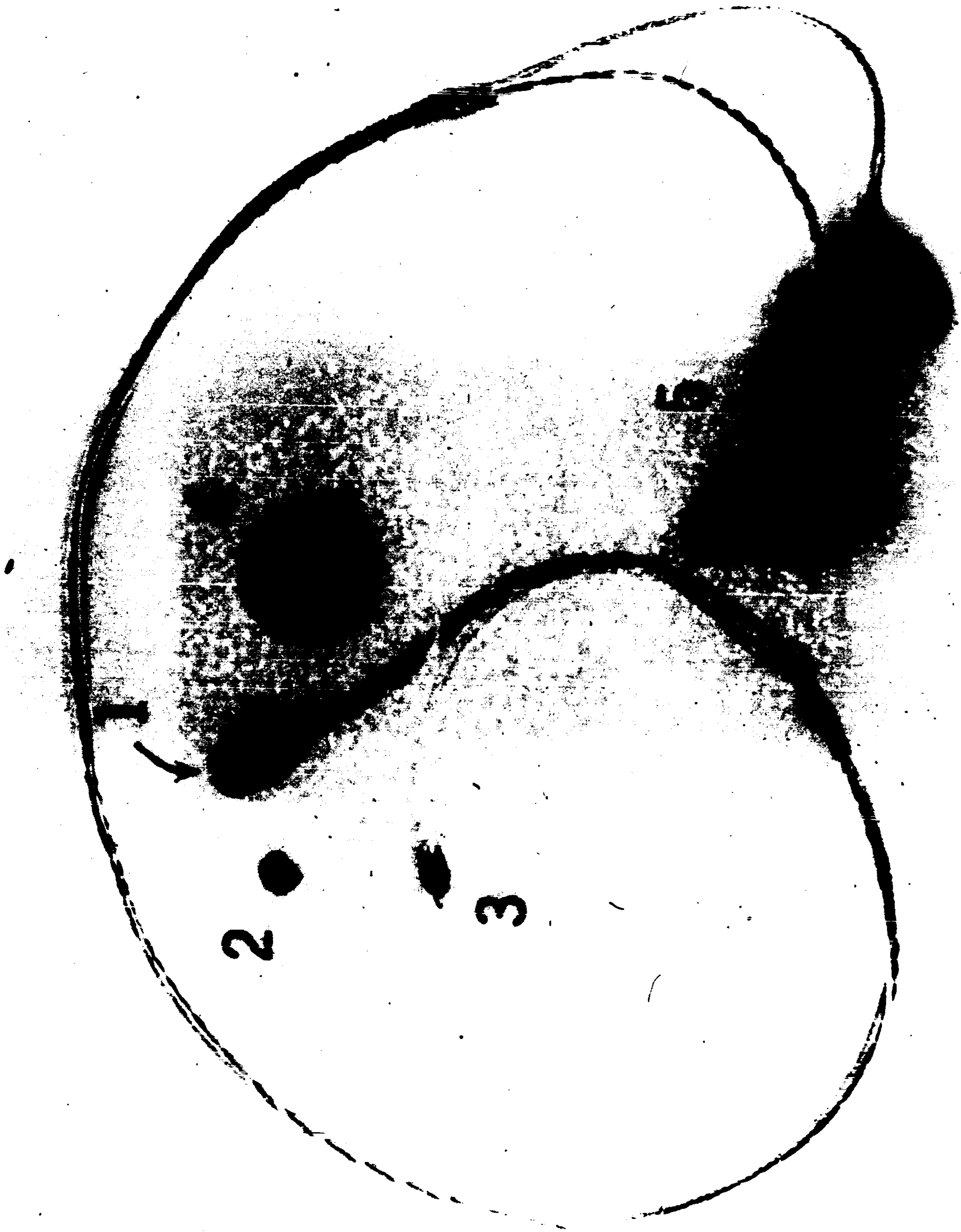


Figure 25 (Extinction)

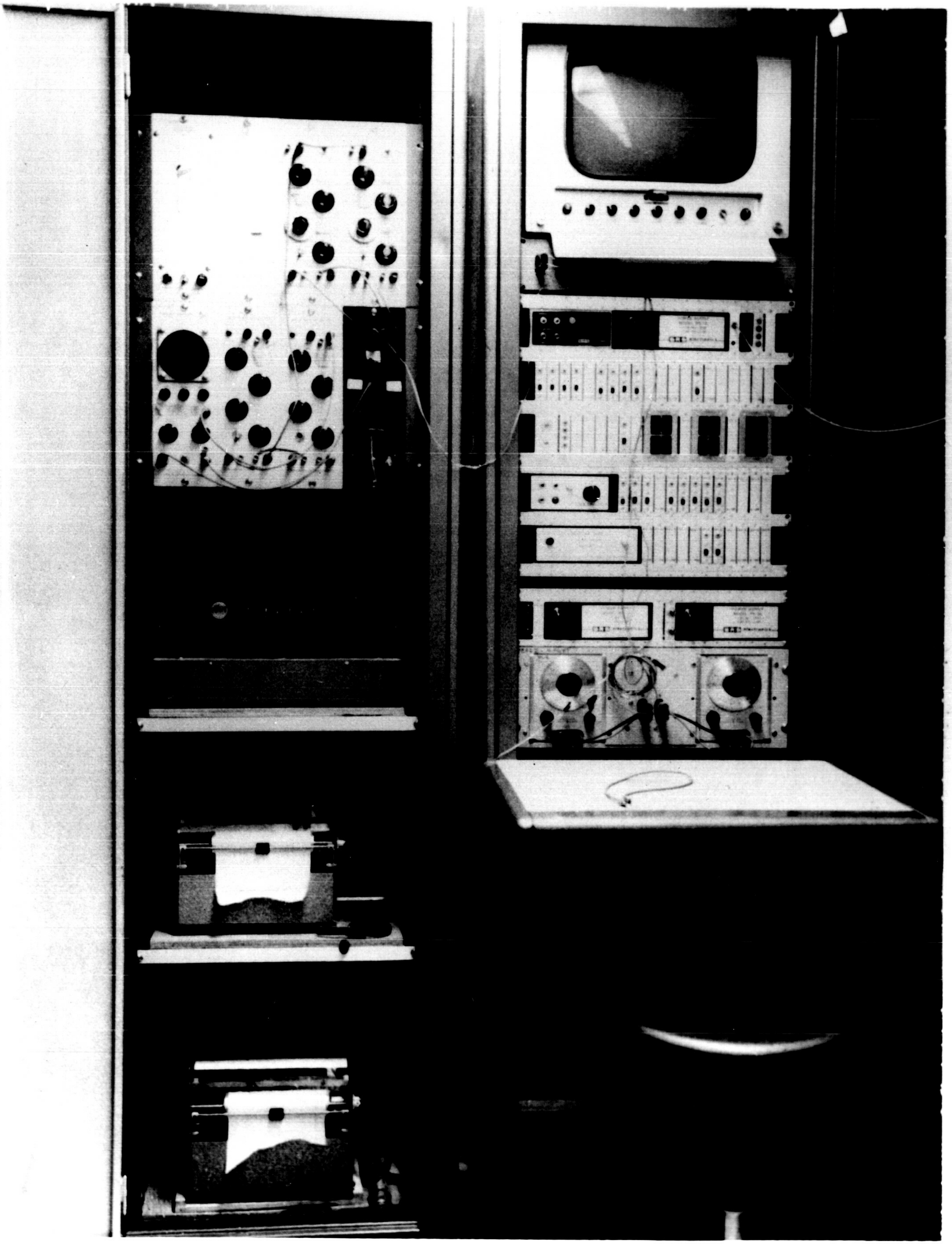
JOCK August 3, 1964

Photographs 1 to 8

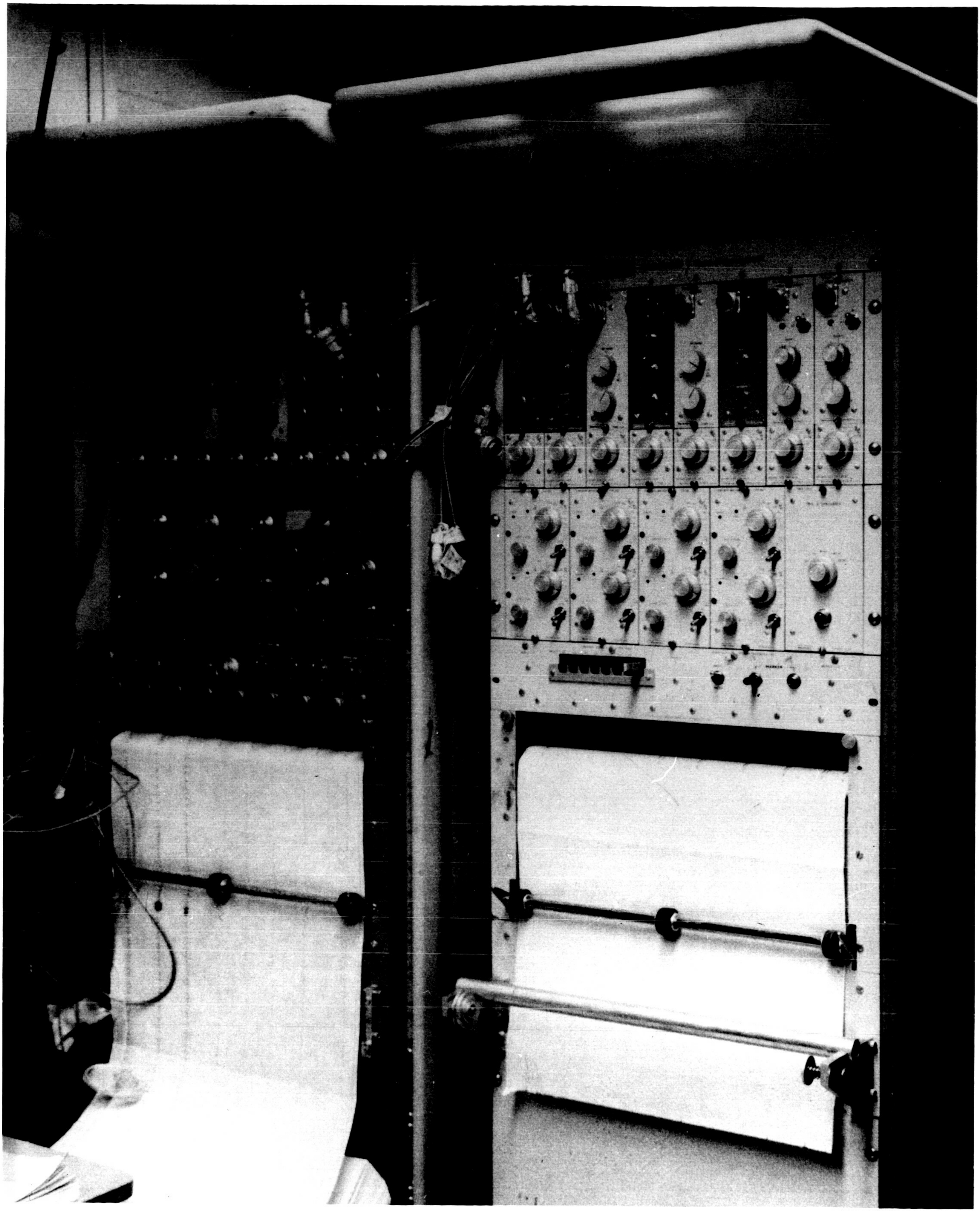
Legend for Photograph 1. Shows an electromagnetic flow-probe which was used in renal artery implantations. Compare its size with the diameter of a one-cent piece next to the transducer. 1) flow-probe pick-up, 2) wedge, 3) ground, 4) one-cent piece, 5) connectors.


1
2
3
5

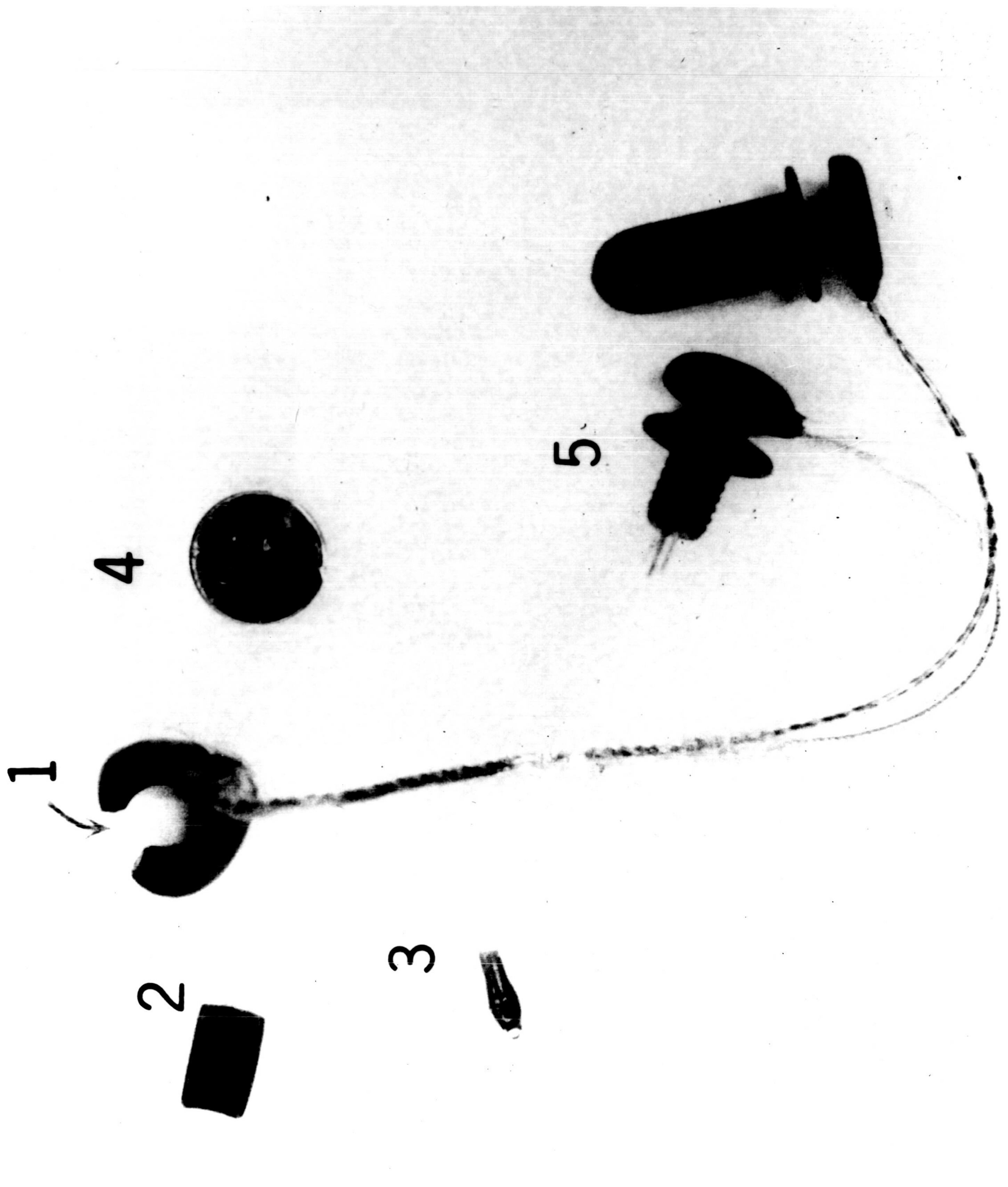
Legend for Photograph 2. Control and monitoring systems using solid state programming devices; tektronic equipment and visual displaying equipment



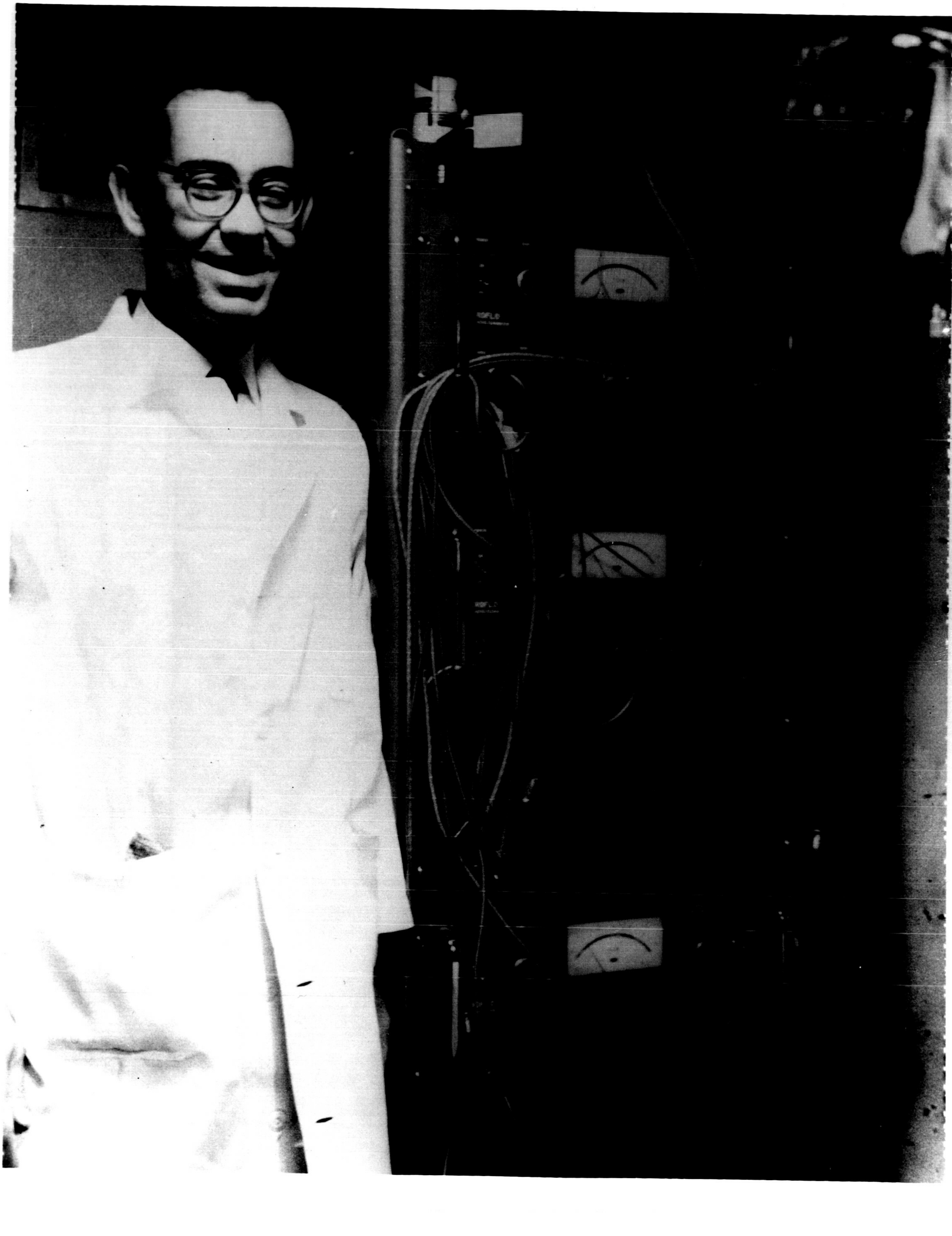
Legend for Photograph 3. Shows Offner polygraphs which are used for recording physiological variables.



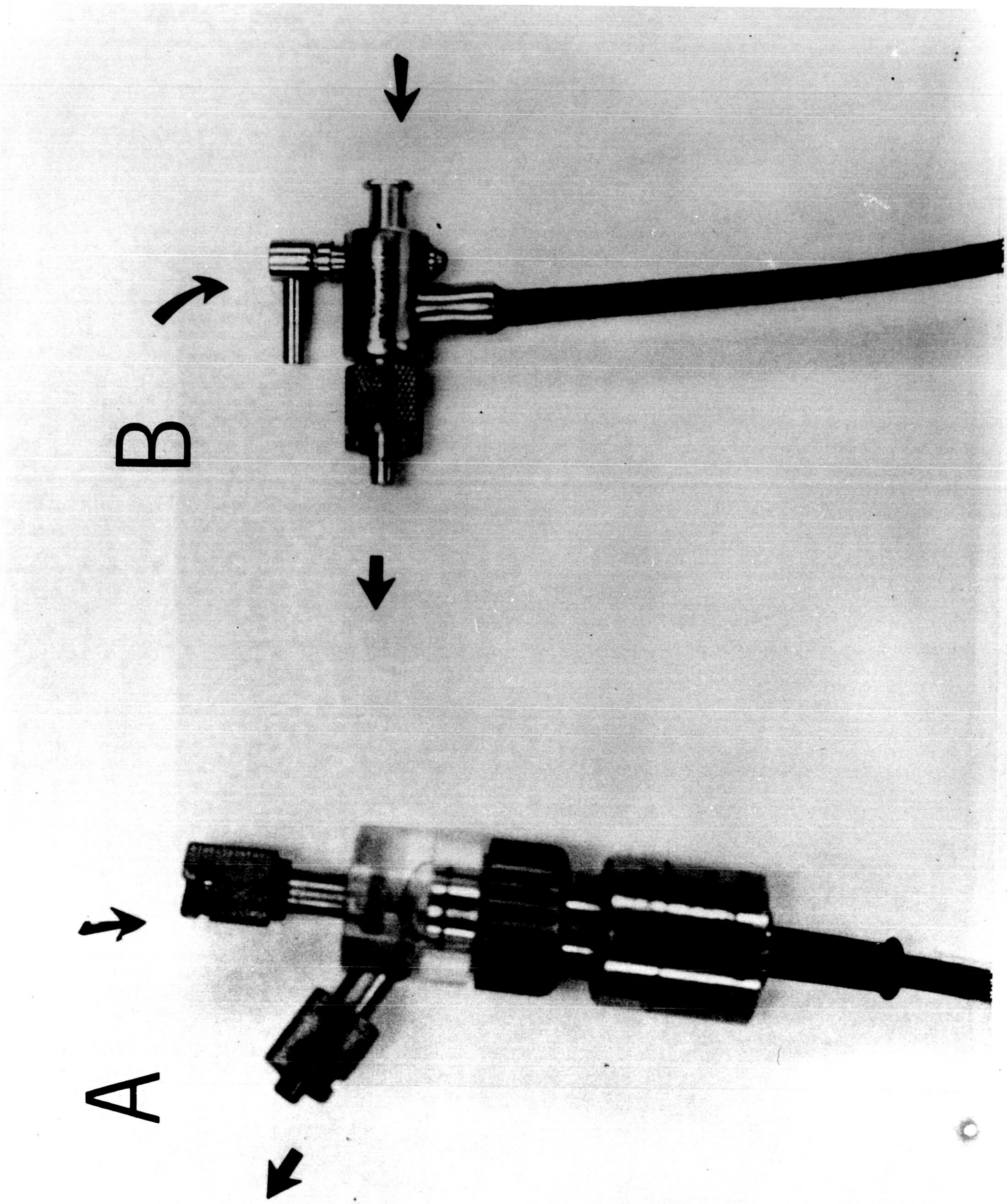
Legend for Photograph 4. Flow-probe which is normally used for implantation around large arteries such as the ascending aorta. Compare the size of the flow-probe with a one-cent piece. 1) shows the flow-probe pick-up, 2) shows the slot wedge, 3) ground, 4) one-cent piece, 5) are the connectors.


1
2
3
4
5

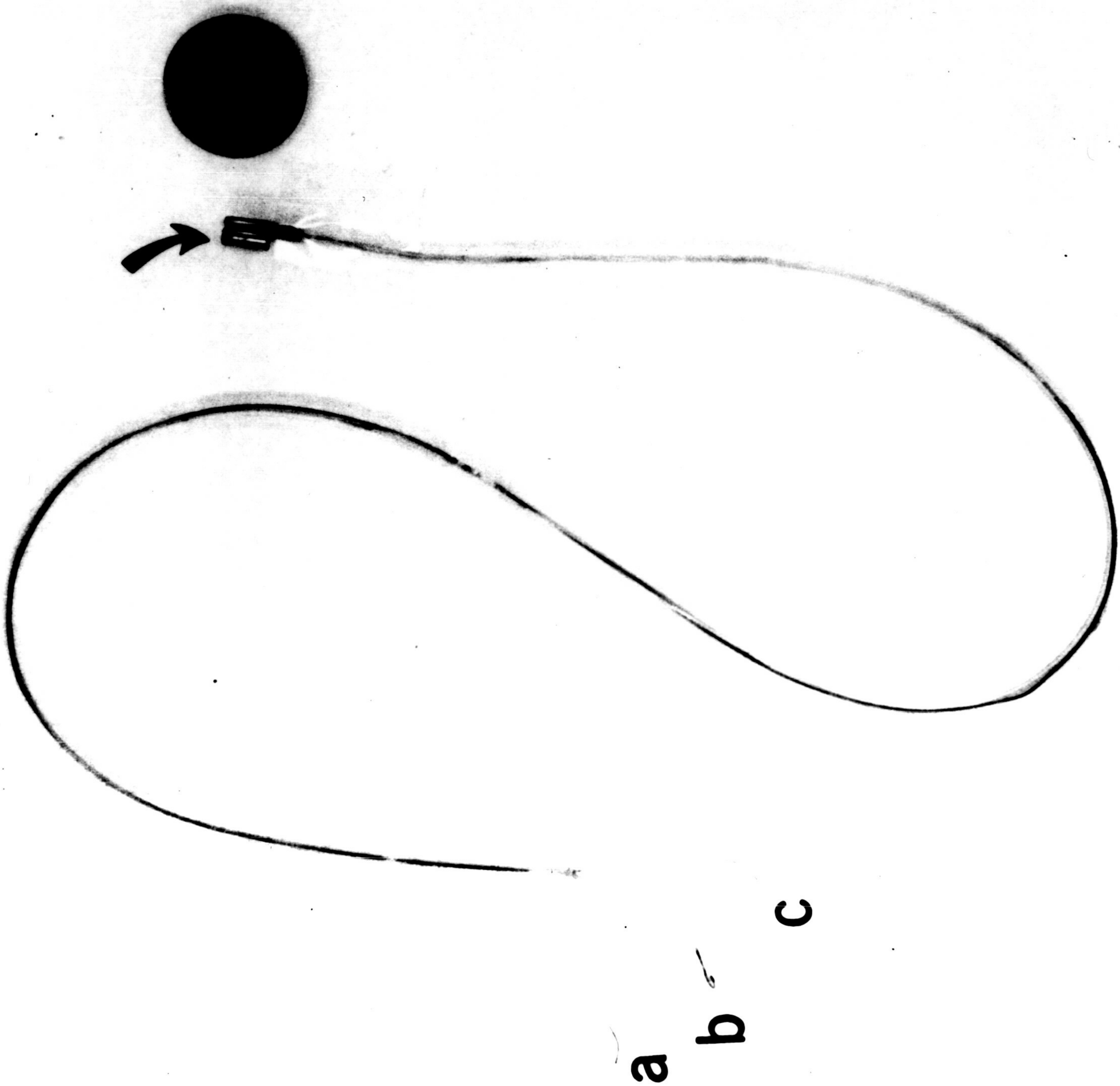
Legend for Photograph 5. Assembly of three K-2000 electromagnetic flowmeters to measure simultaneous blood flow from several arteries.



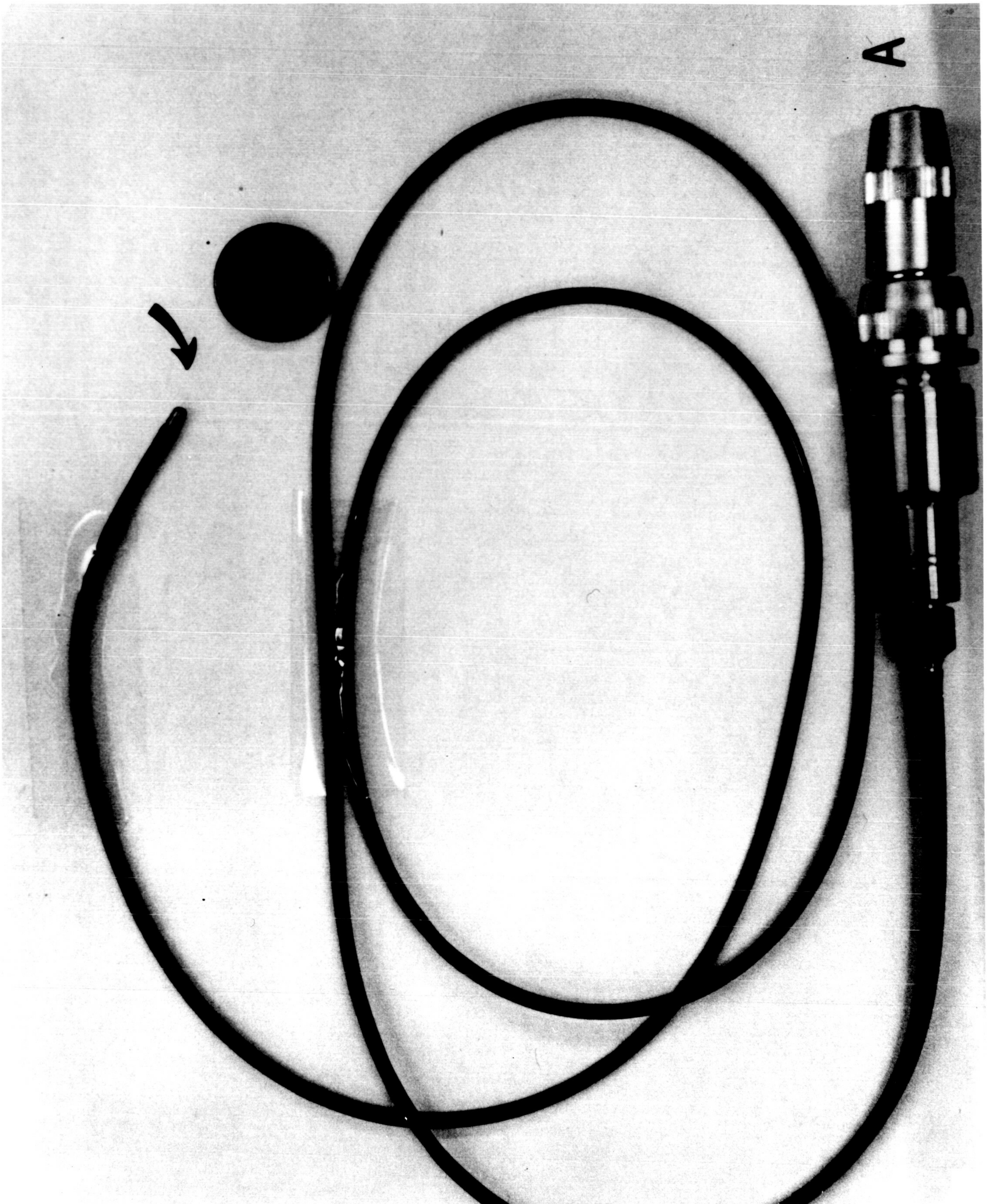
Legend for Photograph 6. Illustrates 2 Statham strain-gauges for measuring direct blood pressure from catheters implanted chronically in arteries. A) shows a large size transducer P23De, B) shows a small strain-gauge type SF4.


B
A

Legend for Photograph 7. Illustrates extra-arterial blood pressure transducer.

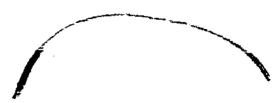

a
b
c

Legend for Photograph 8. Intra-arterial transducer PT7.


A

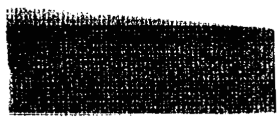
SAMPLES 1 and 2

Sample #1. A sample of teflon coated stainless-steel wire used for obtaining electrocardiograms.



Sample #2.

A. Aluminum cloth sample.



B. Stockinette sample.

C. Waterproof military tape sample.